File

AERONAUTICS AND SPACE ENGINEERING BOARD

AERONAUTICS ASSESSMENT COMMITTEE

MARCH 16-17, 1977

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LEWIS RESEARCH CENTER
CLEVELAND, OHIO 44135

(NASA-TM-85594) AERONAUTICS AND SPACE ENGINEERING BOARD: AERONAUTICS ASSESSMENT COMMITTEE (NASA) 263 p HC A12/MF A01 N84-22771
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G3/31 00501

AERONAUTICS AND SPACE ENGINEERING BOARD

AERONAUTICS ASSESSMENT COMMITTEE

AGENDA

Wednesday, March 16

8:00- 8:15am	Welcome and Center Overview	Dr. B. Lundin
8:15- 8:45am	Introduction to Aeronautics Program	Mr. W. Stewart
8:45-10:00am	MATERIALS AND STRUCTURES R&T	Mr. R. Hall
	High Temperature Engine Materials	Dr. H. Probst
	Fatigue and Fracture Life Prediction	Mr. M. Hirschberg
	Composite Materials and Structures	Mr. J. Freche
10:00-10:15am	Coffee Break	
10:15-11:15am	PROPULSION ENVIRONMENTAL IMPACT MINIMIZATION	
	Propulsion Noise Research	Dr. C. Feiler
	Propulsion Pollution Reduction	Mr. D. Petrash
11:15-12:30pm	PROPULSION COMPONENTS	
	Inlets and Nozzles	Mr. D. Bowditch
	Fan, Compressor and Turbine Research	Mr. M. Hartmann, Mr. H. Rohlik
12:30- 1:30pm	Lunch	
1:30- 3:00pm	PROPULSION COMPONENTS (CONTINUED)	
	Combustors, Augmentation	Mr. D. Petrash
	Power Transfer Research	Mr. W. Anderson
	Fuel Research	Mr. J. Grobman
	Instrumentation	Dr. N. Wenger
3:00- 5:00pm	AIRBREATHING ENGINE SYSTEMS	
	Propulsion Controls Research	Mr. D. Drain
	Full-Scale Engine Research	Mr. R. Willoh
	V/STOL Propulsion Research	Mr. R. Luidens
	Advanced Engine Concepts	Mr. R. Weber
	Advanced General Aviation Propulsion Research	Dr. E. Willis, Jr.
	Adjourn	
5:30pm	Social Hour and Dinner - Guerin House	

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Thursday, March 17

8:00-10:00am	Center Director Discussion of Issues	Dr. B. Lundin
10:00-12:30pm	Committee Discussion of Presentations	
12:30- 1:30pm	Lunch	
1:30- 2:30pm	Center Presentations as Directed	
2:30- 5:00pm	Executive Discussion Analysis and Summary	

CENTER OVERVIEW

PRINCIPAL ROLES OF LEWIS

- AIR BREATHING PROPULSION SYSTEMS
- LAUNCH VEHICLE DEVELOPMENT AND OPERATION
- SPACE PROPULSION SYSTEMS TECHNOLOGY
- SPACE ENERGY PROCESSES AND TECHNOLOGY
- TERRESTRIAL ENERGY TECHNOLOGY AND APPLICATIONS
- HIGH POWER SPACE COMMUNICATIONS

AREAS OF TECHNICAL EXCELLENCE

- COMPRESSOR AND TURBINE AERODYNAMICS
- COMBUSTION
- MATERIALS
- MECHANICAL POWER TRANSMISSION
- FRACTURE MECHANICS AND FATIGUE
- ELECTRONIC POWER PROCESSING
- ELECTRIC PROPULSION
- ENERGY CONVERSION PROCESSES AND SYSTEMS
- LAUNCH VEHICLE ENGINEERING AND OPERATIONS

RECENT PROGRAM TRENDS IN AERONAUTICS AT LEWIS

- SHIFT TOWARDS CIVIL NEEDS
    - o ENVIRONMENT
    - o ENERGY
    - o ECONOMY
- GRADUALLY DECLINING R&T BASE; GROWTH IN "PROJECTS", EXPERIMENTAL ENGINES
- RECENT INTEREST, SUPPORT, BY NASA MANAGEMENT
- RECENTLY GROWING RELATIONS WITH SMALL ENGINE BUILDERS
- LINE AND CLOSE RELATIONS WITH USAF APL IN R&T BASE
- STABILITY OF STAFFING, ORGANIZATION
- GOOD RELATIONS WITH UNIVERSITIES, INDUSTRY
- INTRODUCTION OF A FUNDING "BOW-WAVE"

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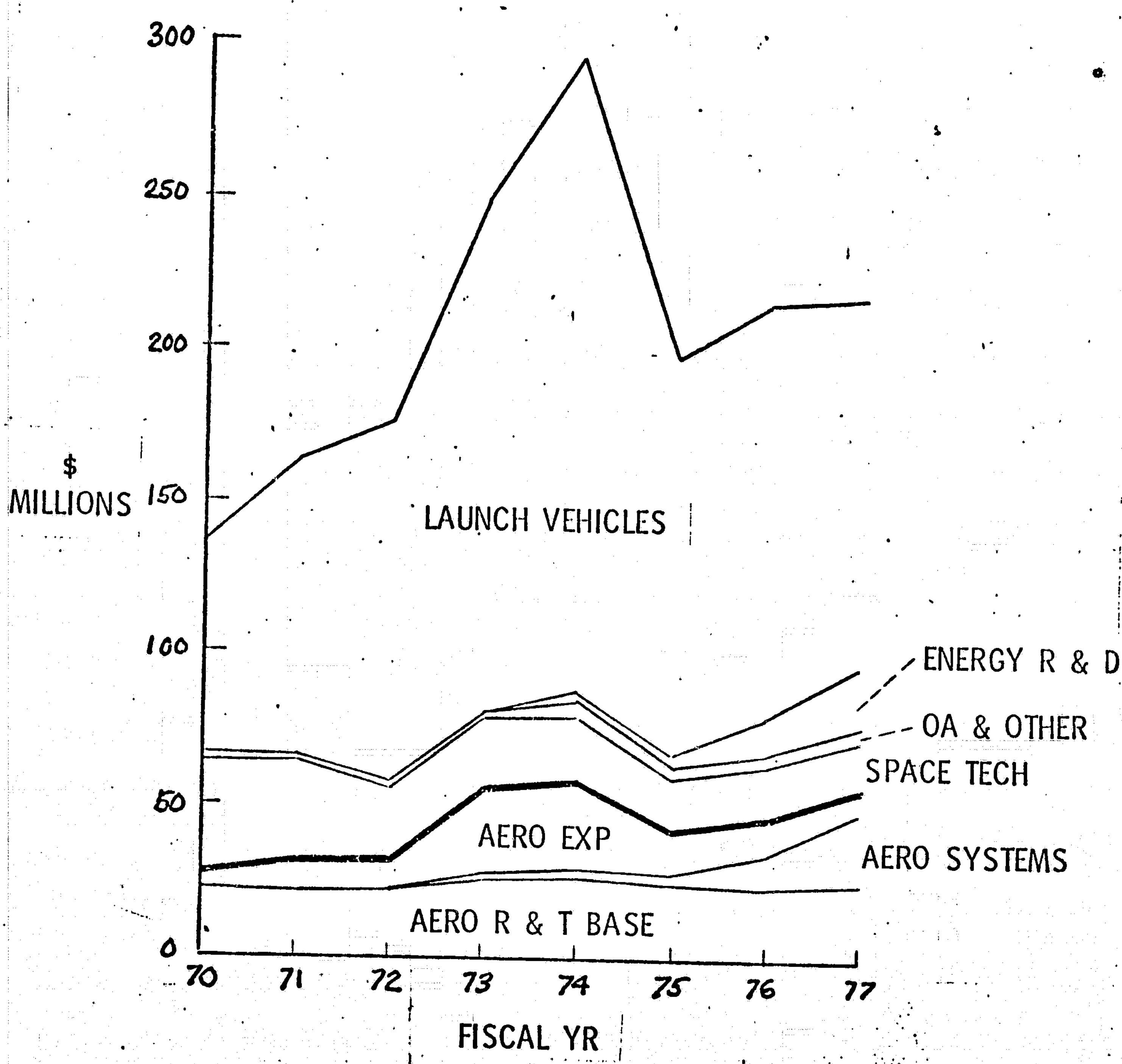
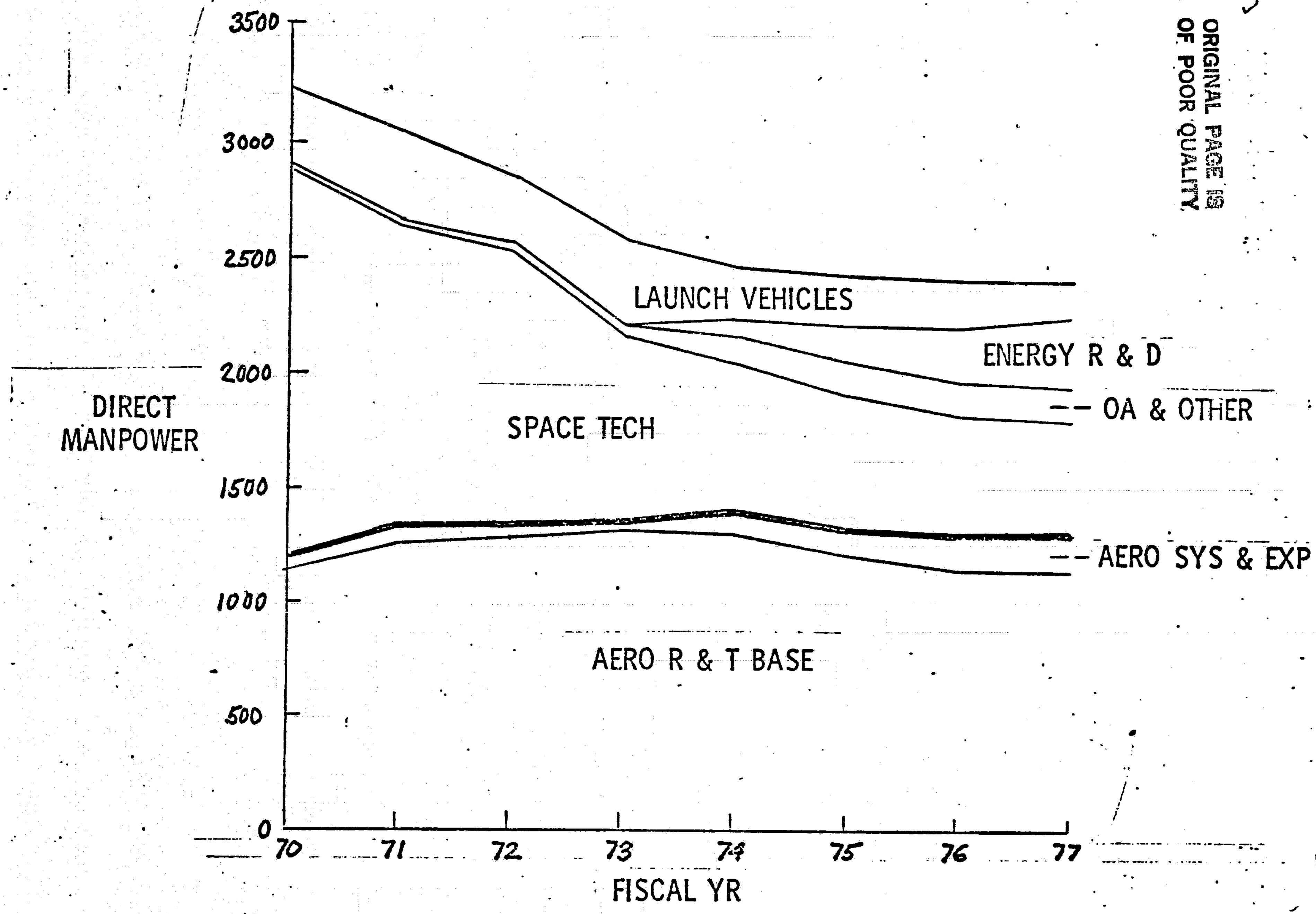
LEWIS RESEARCH CENTER
R & D FUNDING



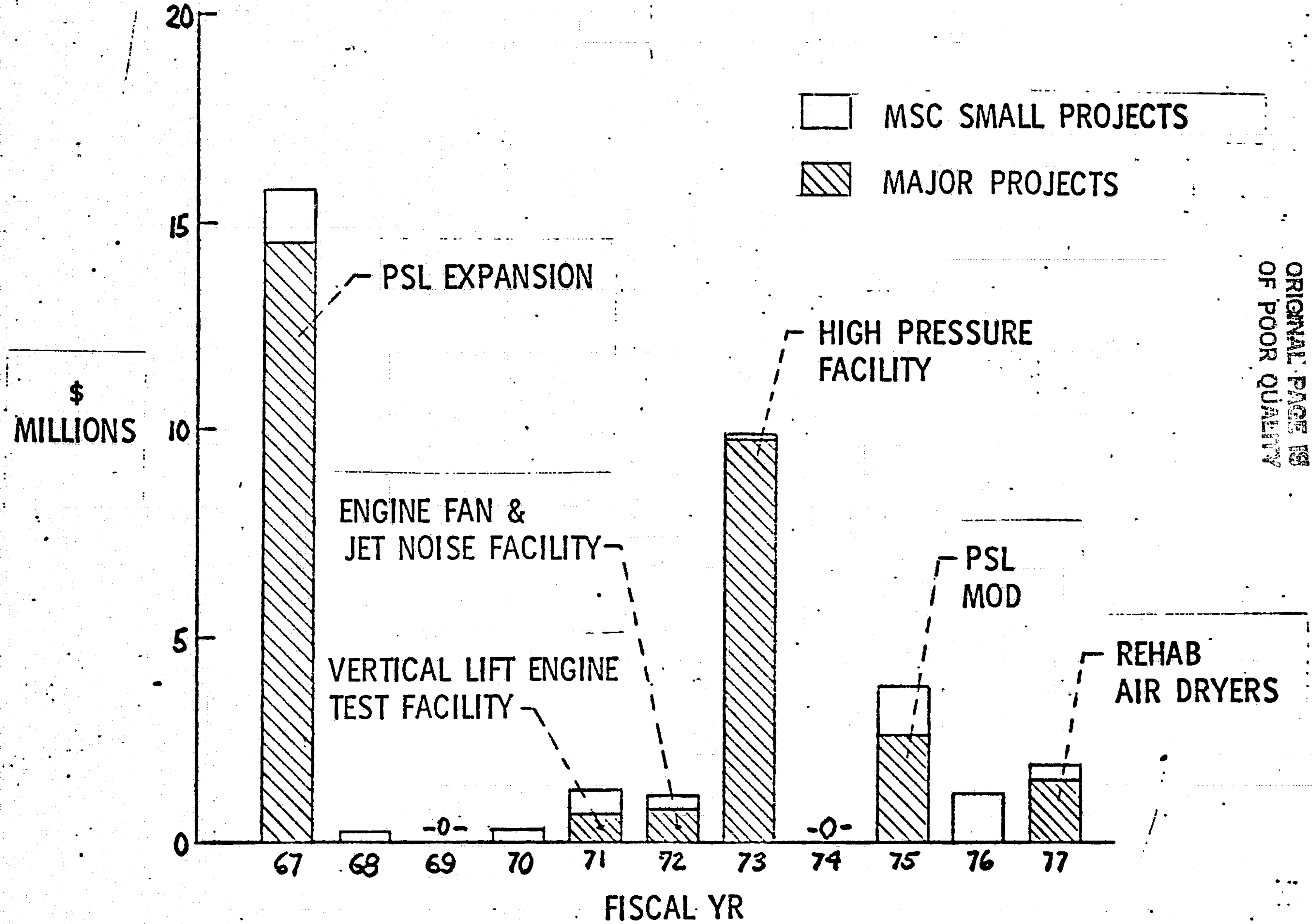
LEWIS RESEARCH CENTER

DIRECT MANPOWER DISTRIBUTION



LEWIS RESEARCH CENTER

AERONAUTICS FACILITIES FUNDING (C OF F)



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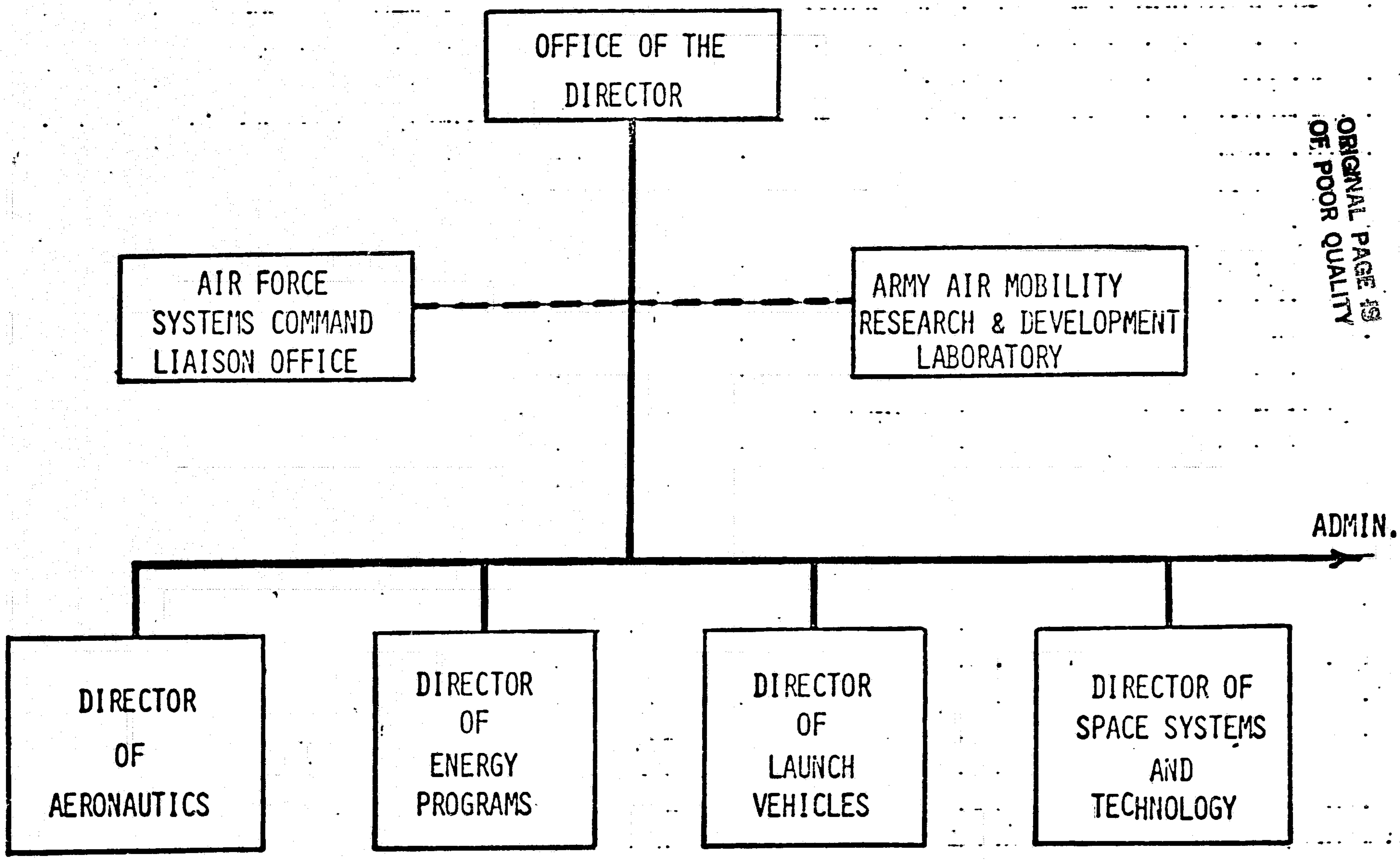
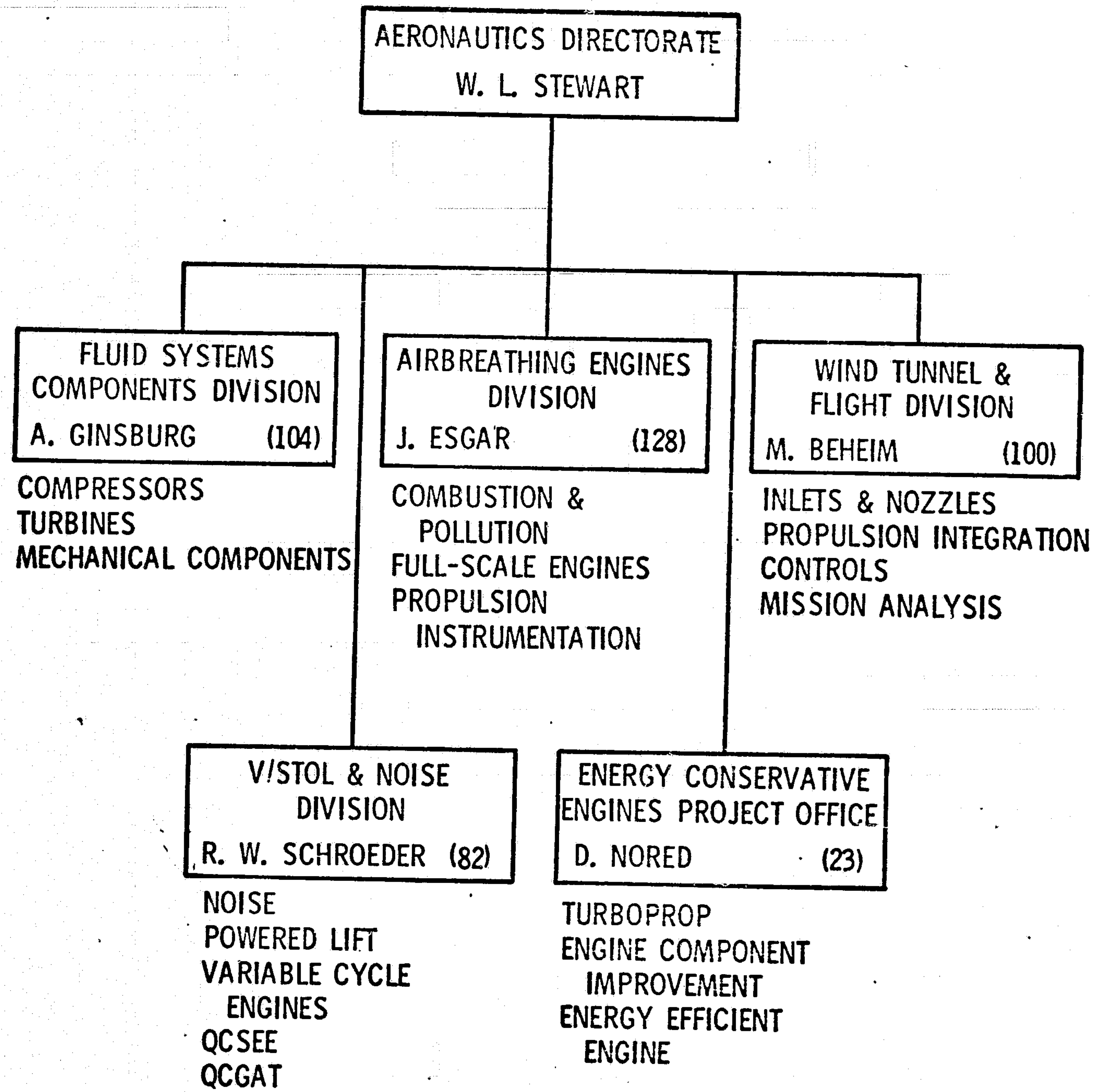
INTRODUCTION TO AERONAUTICS PROGRAM


OFFICE OF THE DIRECTOR
AIR FORCE SYSTEMS COMMAND LIAISON OFFICE
ARMY AIR MOBILITY RESEARCH & DEVELOPMENT LABORATORY
ADMIN.
DIRECTOR OF AERONAUTICS
DIRECTOR OF ENERGY PROGRAMS
DIRECTOR OF LAUNCH VEHICLES
DIRECTOR OF SPACE SYSTEMS AND TECHNOLOGY



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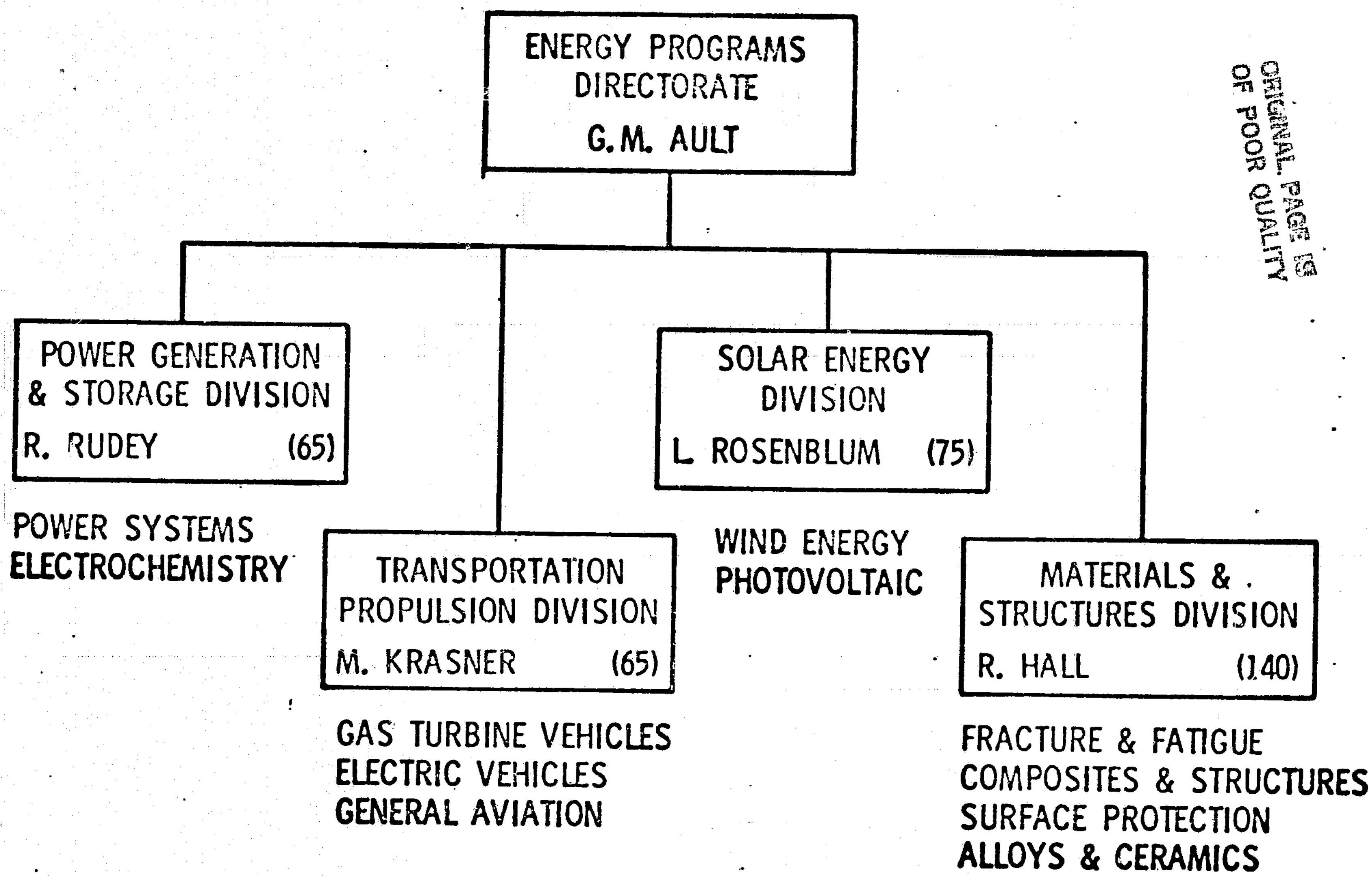
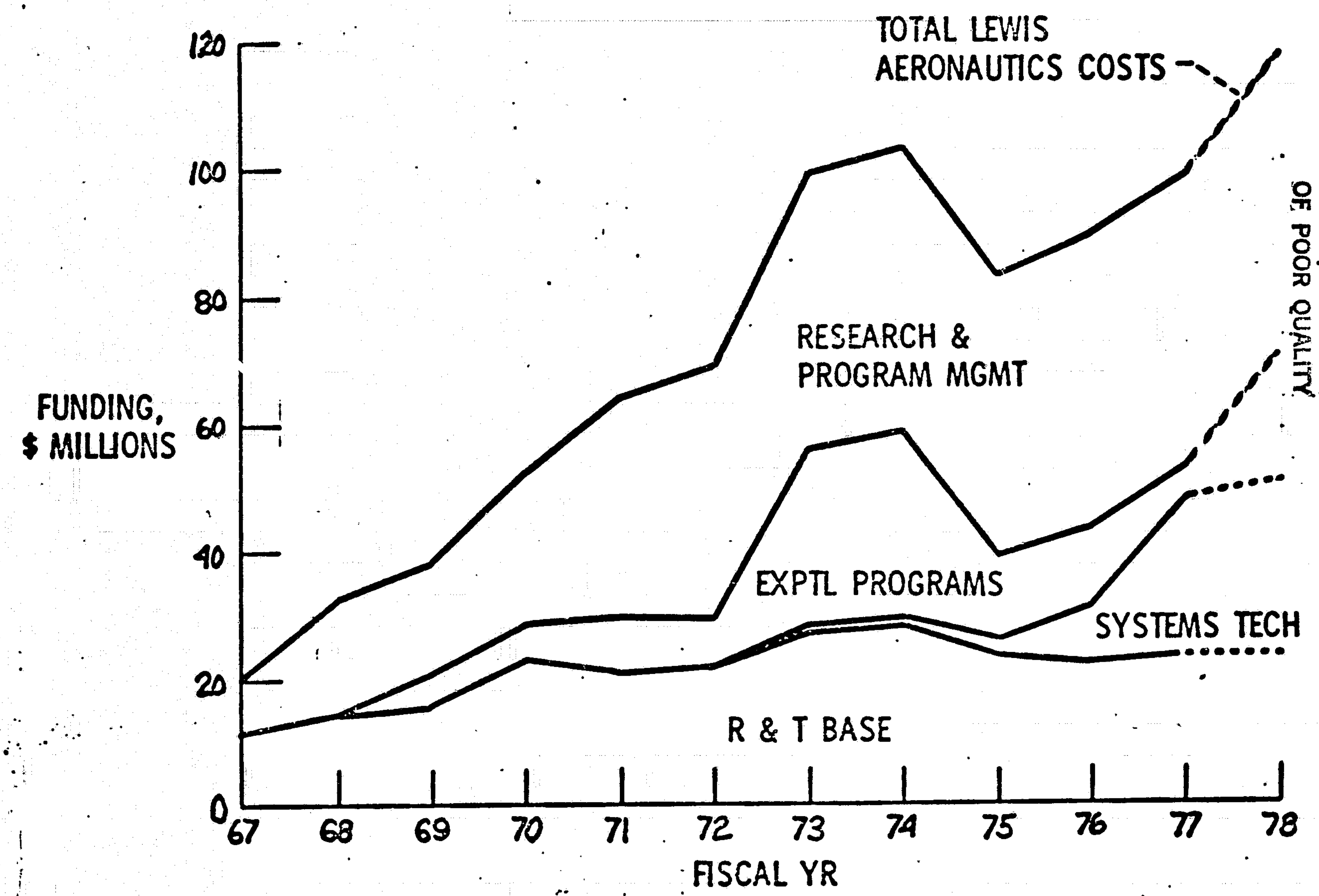
10-1-76


ENERGY PROGRAMS DIRECTORATE
G.M. AULT
POWER GENERATION & STORAGE DIVISION
R. RUDEY (65)
POWER SYSTEMS
ELECTROCHEMISTRY
TRANSPORTATION PROPULSION DIVISION
M. KRASNER (65)
GAS TURBINE VEHICLES
ELECTRIC VEHICLES
GENERAL AVIATION
SOLAR ENERGY DIVISION
L. ROSENBLUM (75)
WIND ENERGY
PHOTOVOLTAIC
MATERIALS & STRUCTURES DIVISION
R. HALL (140)
FRACTURE & FATIGUE
COMPOSITES & STRUCTURES
SURFACE PROTECTION
ALLOYS & CERAMICS

LEWIS RESEARCH CENTER
AERONAUTICS FUNDING HISTORY



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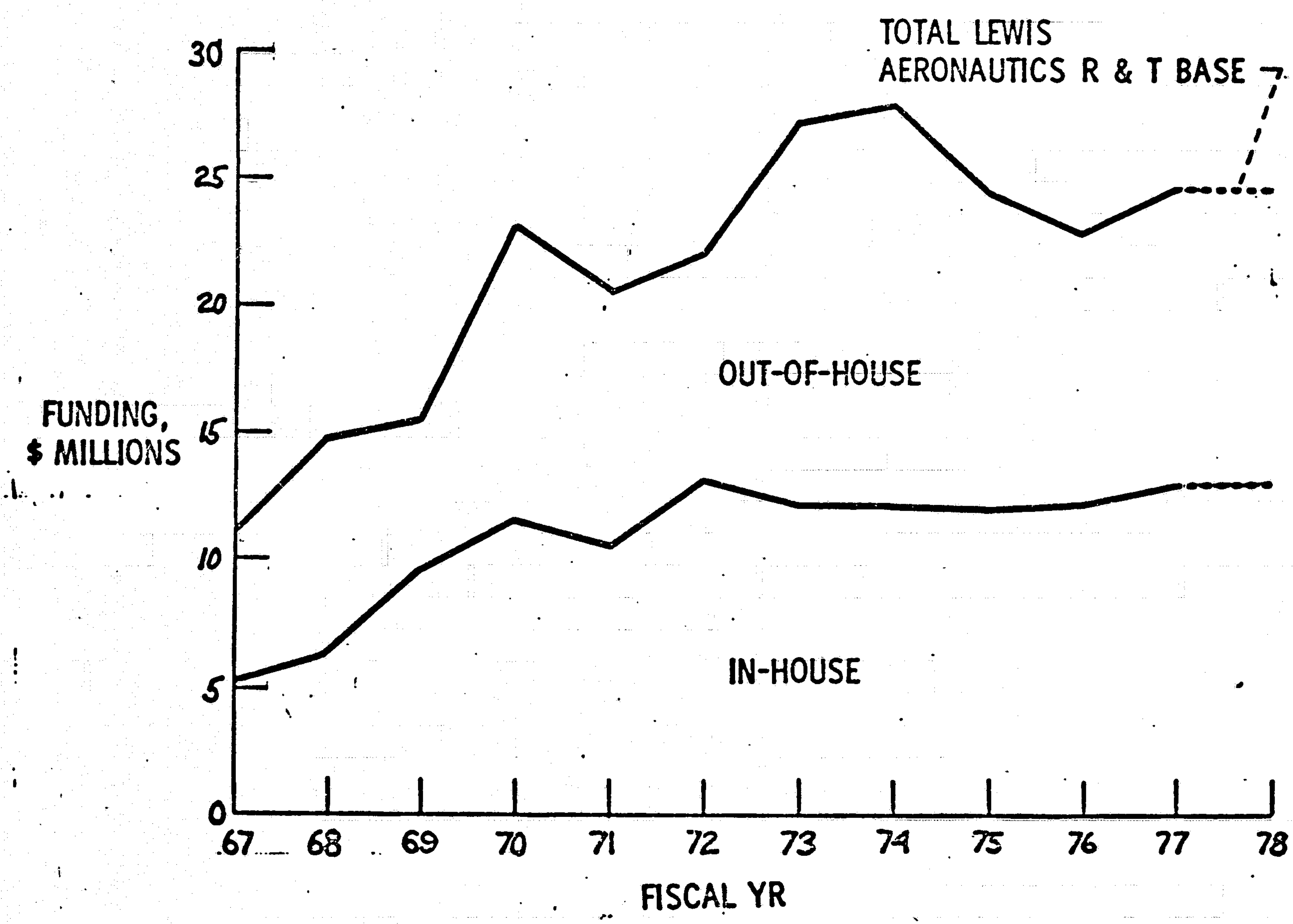
AERONAUTICS R & T BASE HISTORY



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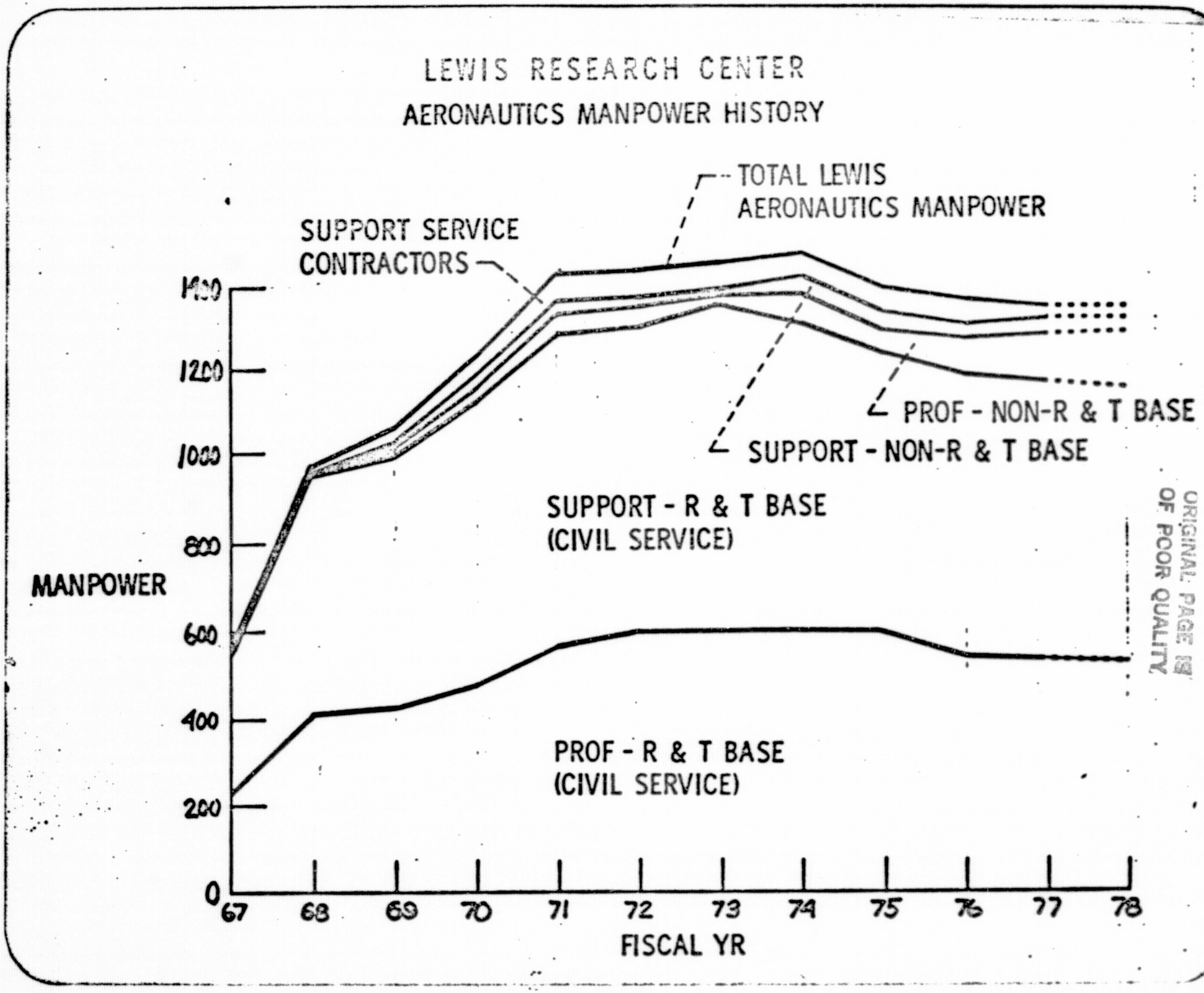

LEWIS RESEARCH CENTER
AERONAUTICS MANPOWER HISTORY
TOTAL LEWIS AERONAUTICS MANPOWER
SUPPORT SERVICE CONTRACTORS
PROF - NON-R & T BASE
SUPPORT - NON-R & T BASE
SUPPORT - R & T BASE (CIVIL SERVICE)
PROF - R & T BASE (CIVIL SERVICE)
MANPOWER
1400
1200
1000
800
600
400
200
0
67
68
69
70
71
72
73
74
75
76
77
78
FISCAL YR

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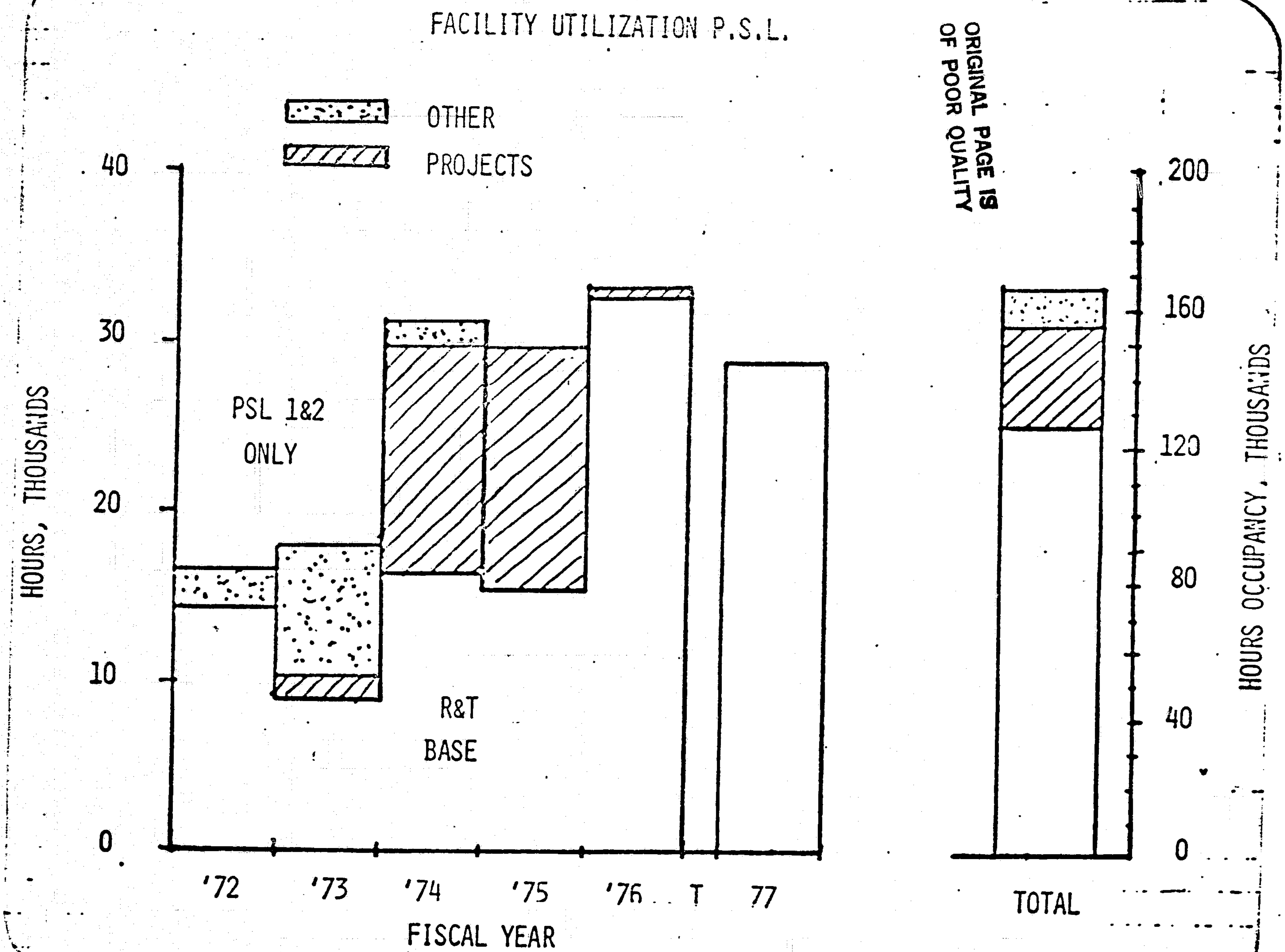
BLACK AND WHITE PHOTOGRAPH



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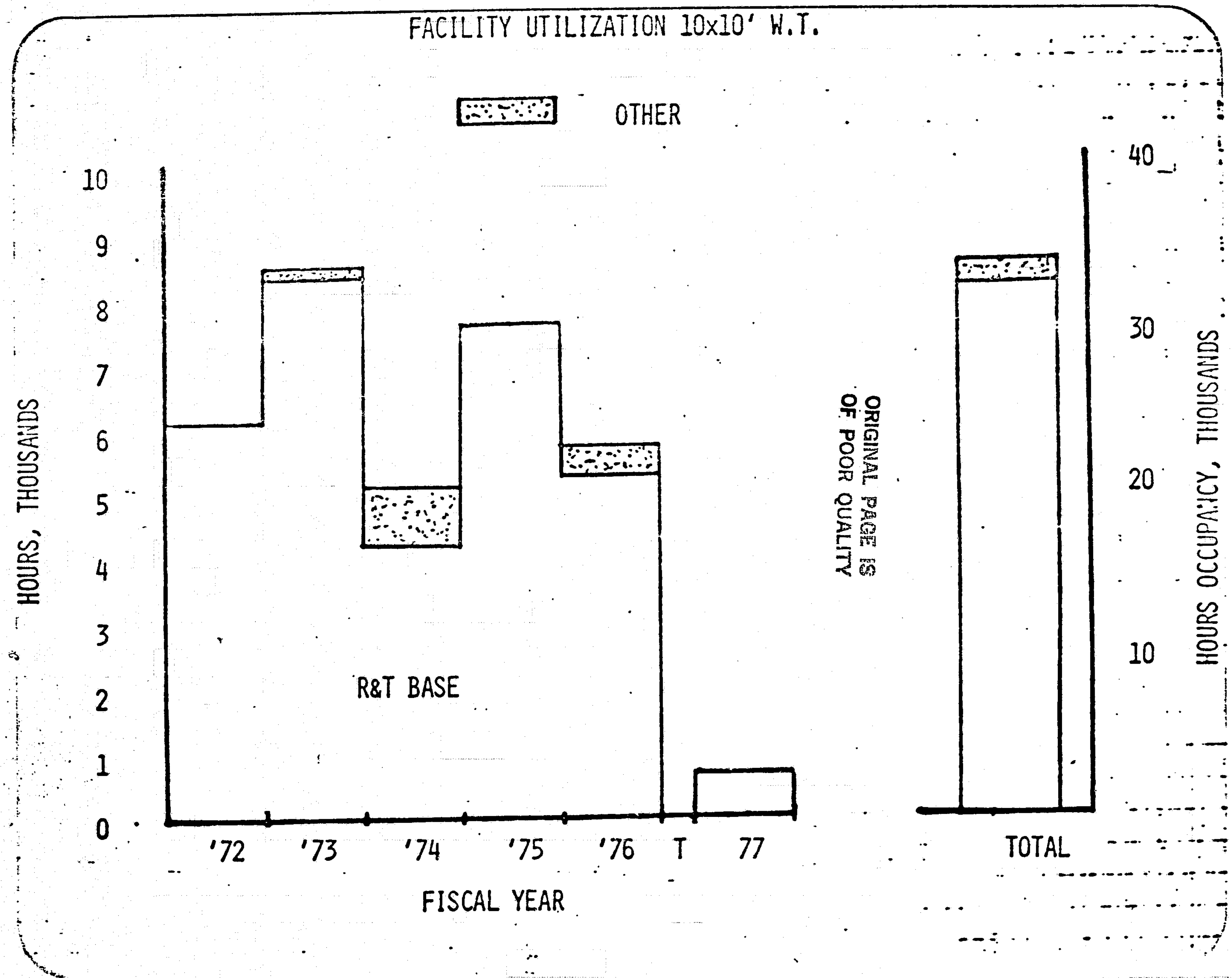

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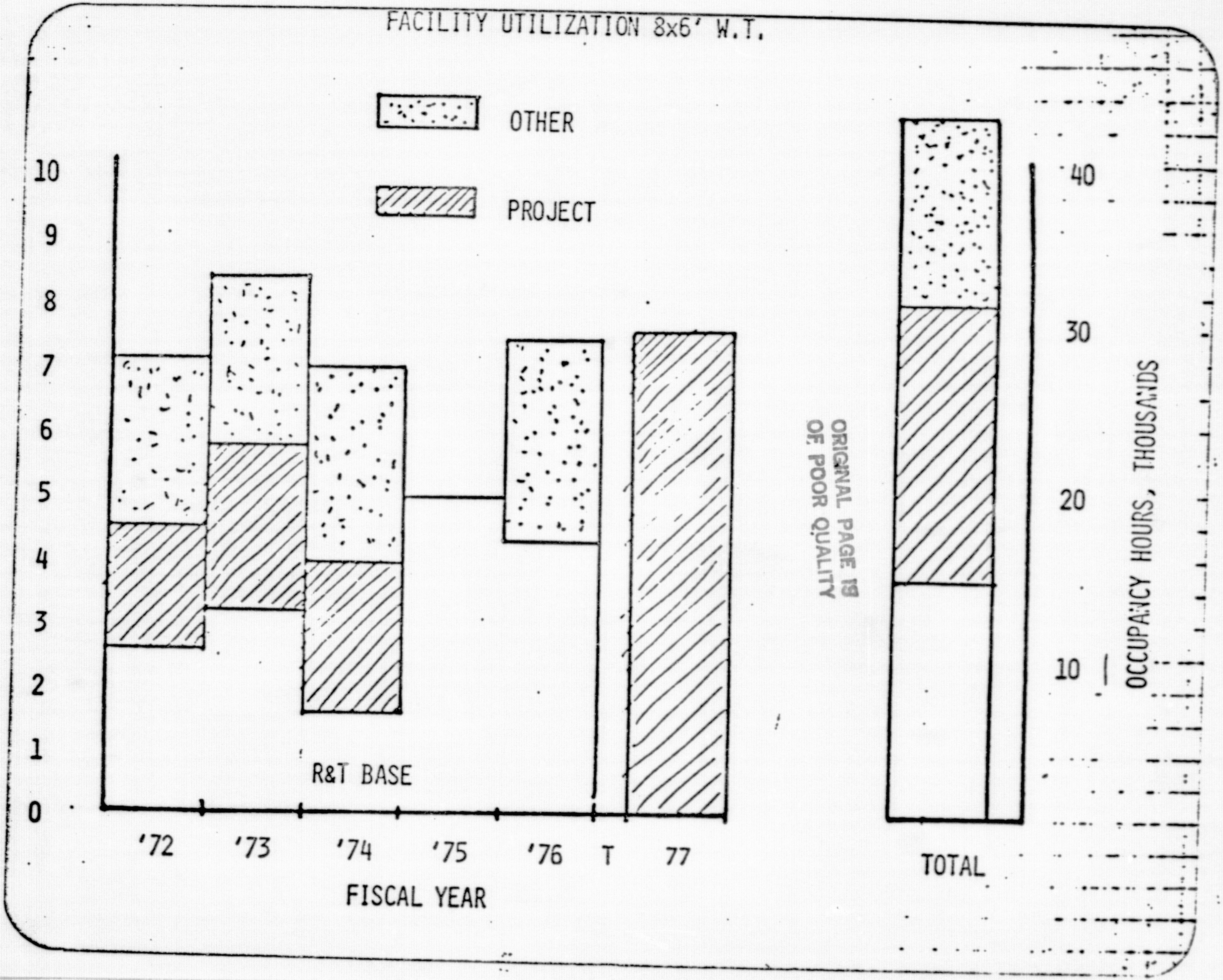
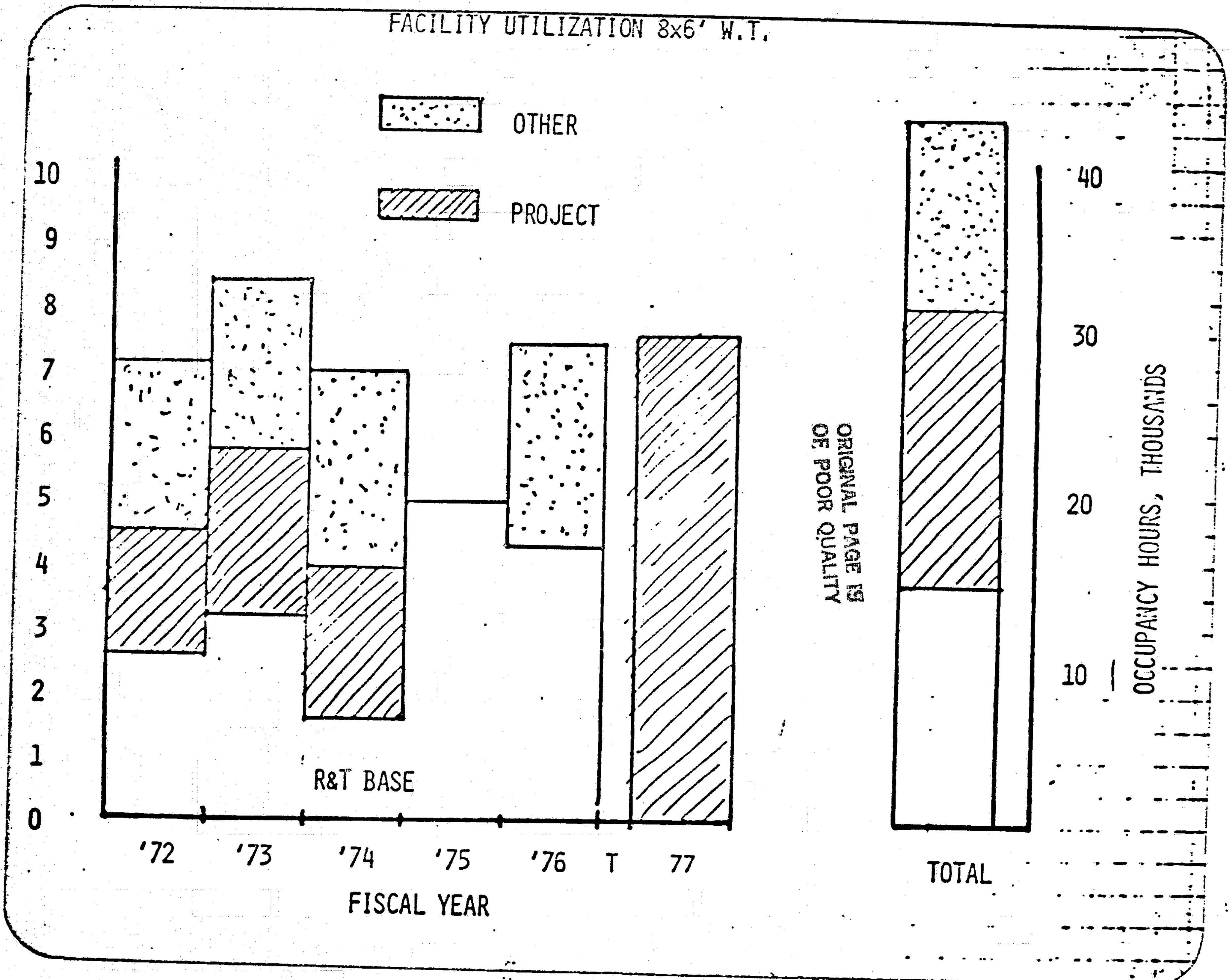

FACILITY UTILIZATION 8x6' W.T.
OTHER
PROJECT
10
9
8
7
6
5
4
3
2
1
0
R&T BASE
'72
'73
'74
'75
'76
T
77
FISCAL YEAR
TOTAL
40
30
20
10
OCCUPANCY HOURS, THOUSANDS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T
77
FISCAL YEAR
TOTAL
10
20
30
40
OCCUPANCY HOURS, THOUSANDS
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MISSIONS OF DISCIPLINE TEAMS

- MAINTAIN IN-HOUSE EXPERTISE
- MAINTAIN OPTIMUM BALANCE, IN-HOUSE VS. CONTRACT/GRANT
- SUPPORT TO LEWIS PROJECT/ORGANIZATIONS
- SUPPORT TO OTHER NASA CENTERS/HEADQUARTERS
- SERVICE TO OTHER AGENCIES

PROGRAMS WITH OTHER NASA CENTERS

LANGLEY RESEARCH CENTER

- SCAR
- General Aviation Agriculture
- ACEE
- Nonaxisymmetric Nozzle
- Noise

AMES RESEARCH CENTER

- AMST
- QSRA
- VTOL Technology
- Helicopter Technology
- GASP
- Noise

DRYDEN FLIGHT RESEARCH CENTER

- F-15
- YF-12
- HIMAT

SPACE FLIGHT CENTERS

- Shuttle

AF/NASA INTEGRATED PROGRAMS

FORMAL PROGRAMS IN PROCESS

- FULL-SCALE ENGINE RESEARCH (FSER)
- ADVANCED COMPRESSOR TECHNOLOGY
- AEROELASTIC STABILITY OF FAN AND COMPRESSOR BLADED SYSTEMS
- ADVANCED CONTROL TECHNOLOGY
- LONG-RANGE PLAN CONTROL TECHNOLOGY
- SEAL TECHNOLOGY
- MECHANICAL COMPONENTS AND LUBRICATION TECHNOLOGY
- INSTRUMENTATION TECHNOLOGY
- NOISE TECHNOLOGY
- ALTERNATE FUELS

INFORMAL AGREEMENTS

- EMISSIONS TECHNOLOGY
- THRUST AUGMENTATION TECHNOLOGY
- VARIABLE CYCLE ENGINE TECHNOLOGY
- ADVANCED MATERIALS TECHNOLOGY
- SOLAR CELL AND ELECTROCHEMICAL POWER

PLAN BEING FORMULATED

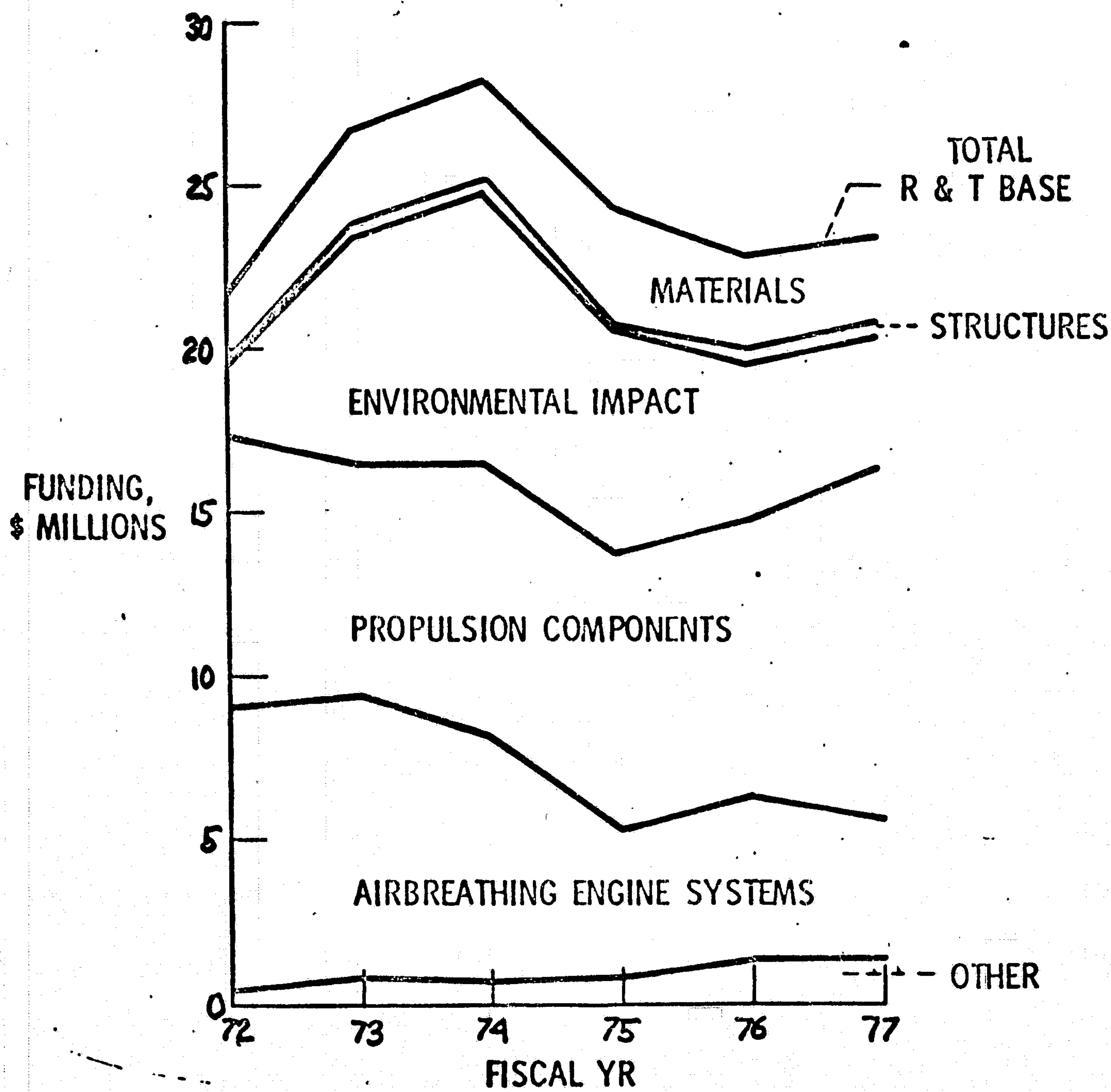
- DISTORTION
- CATALYTIC COMBUSTOR TECHNOLOGY
- ADVANCED TURBINE TECHNOLOGY
- NON-AXISYMMETRIC NOZZLE

NASA AERONAUTICS MISSION OBJECTIVES

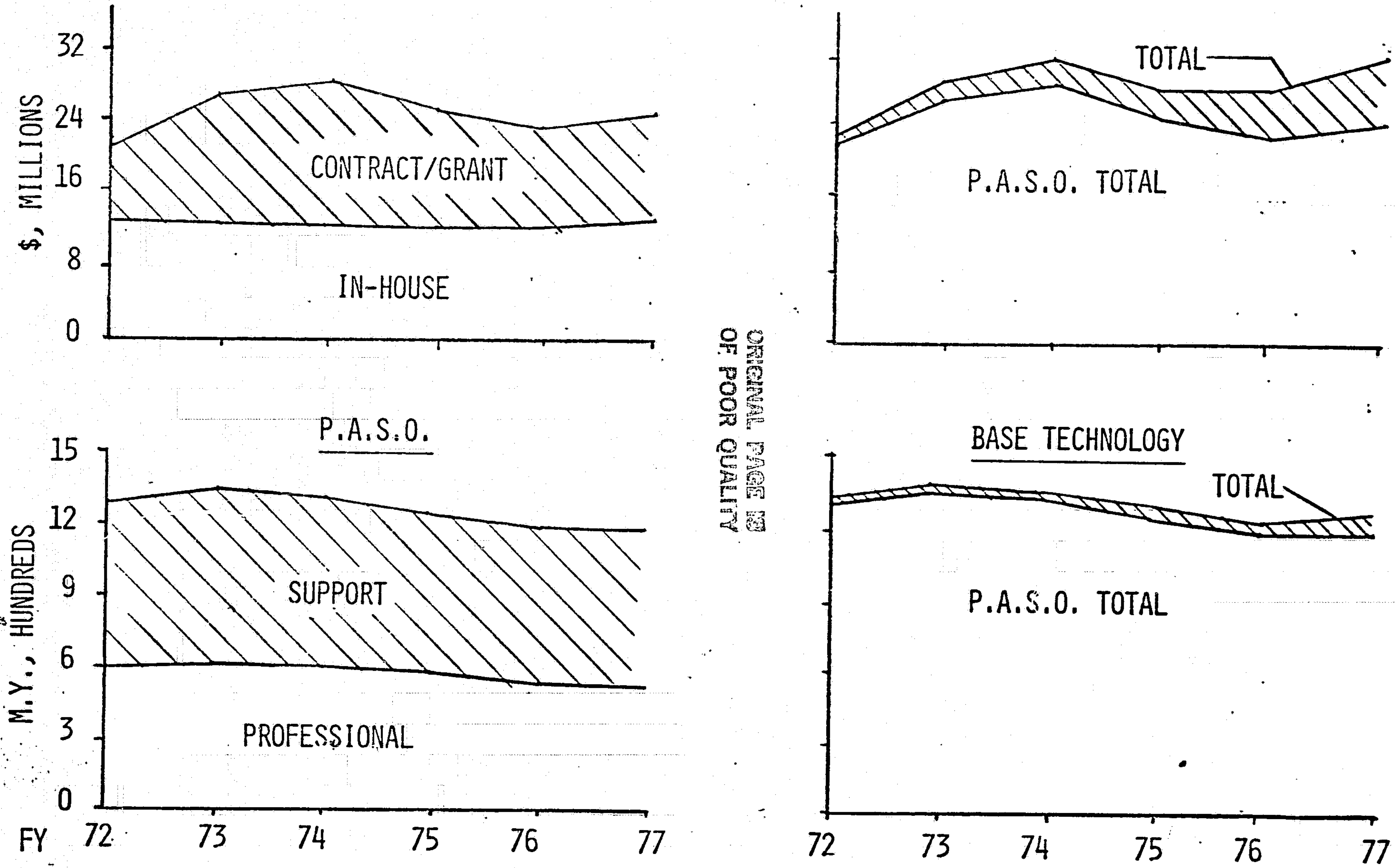
- SAFER , MORE ECONOMICAL, EFFICIENT AND ENVIRONMENTALLY ACCEPTABLE AIR TRANSPORTATION SYSTEM.
- FAVORABLE COMPETITIVE POSITION FOR THE U.S. IN THE INTERNATIONAL AVIATION MARKET PLACE.
- MAINTENANCE OF SUPERIORITY OF U.S. MILITARY AIRCRAFT.

5

LEWIS RESEARCH CENTER
AERONAUTICS DISCIPLINES



AERO R&T BASE SUMMARY



DISCIPLINARY R&T PRESENTATIONS

SUB-PROGRAM CODE	TITLE	SPEAKER
505-01, 02	MATERIALS AND STRUCTURES R&T	R. HALL
	HIGH TEMPERATURE ENGINE MATERIALS	H. PROBST
	FATIGUE & FRACTURE LIFE PREDICTION	M. HIRSCHBERG
	COMPOSITE MATERIALS AND STRUCTURES	J. FRECHE
505-03	PROPULSION ENVIRONMENTAL IMPACT MINIMIZATION	
	PROPULSION NOISE RESEARCH	C. FEILER
	PROPULSION POLLUTION REDUCTION	D. PETRASH
505-04	PROPULSION COMPONENTS	
	INLETS AND NOZZLES	D. BOWDITCH
	FAN, COMPRESSOR AND TURBINE RESEARCH	M. HARTMANN, H. ROHLI
	COMBUSTORS, AUGMENTATION	D. PETRASH
	POWER TRANSFER RESEARCH	W. ANDERSON
	FUEL RESEARCH	J. GROBMAN
	INSTRUMENTATION	N. WENGER
505-05	AIRBREATHING ENGINE SYSTEMS	
	PROPULSION CONTROLS RESEARCH	D. DRAIN
	FULL-SCALE ENGINE RESEARCH	R. WILLOH
	V/STOL PROPULSION RESEARCH	R. LUIDENS
	ADVANCED ENGINE CONCEPTS	R. WEBER
	ADVANCED GENERAL AVIATION PROPULSION RESEARCH	E. WILLIS, JR.

MATERIALS & STRUCTURES

R. W. HALL

FY 77 RESOURCES SUMMARY

MATERIALS

SPECIFIC OBJECTIVE	R&D $M	DMY
HIGH TEMPERATURE ENGINE MATERIALS	2.3	94
FATIGUE, FRACTURE, AND LIFE PREDICTION	0.3	29
SAFER LIGHTWEIGHT AIRCRAFT MATERIALS	0.7	22
	3.3	145

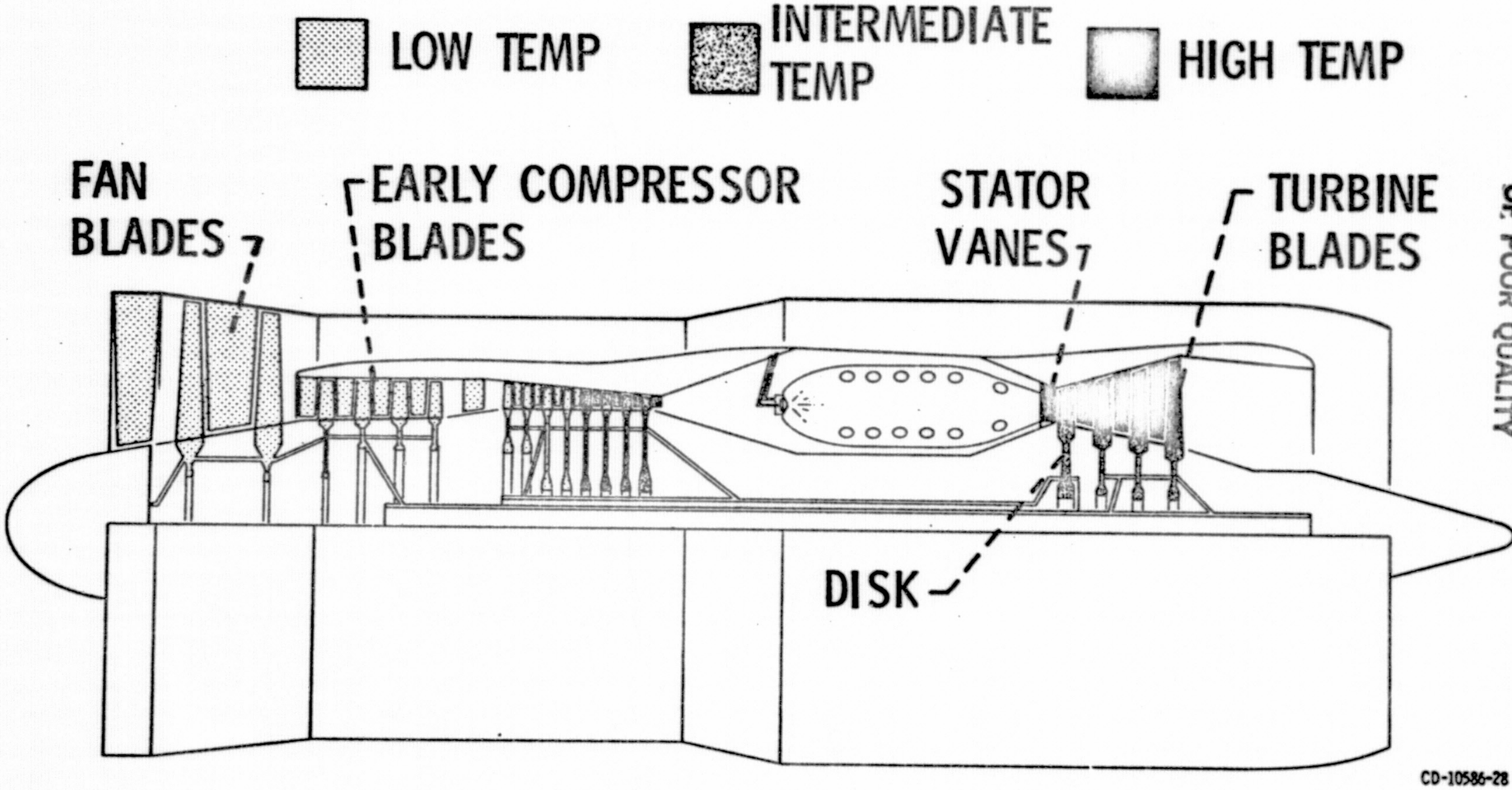
STRUCTURES

ADVANCED AIRCRAFT STRUCTURES	0.2	3

NASA
CS-73101

298-2

SCHEMATIC DIAGRAM OF TURBOFAN ENGINE



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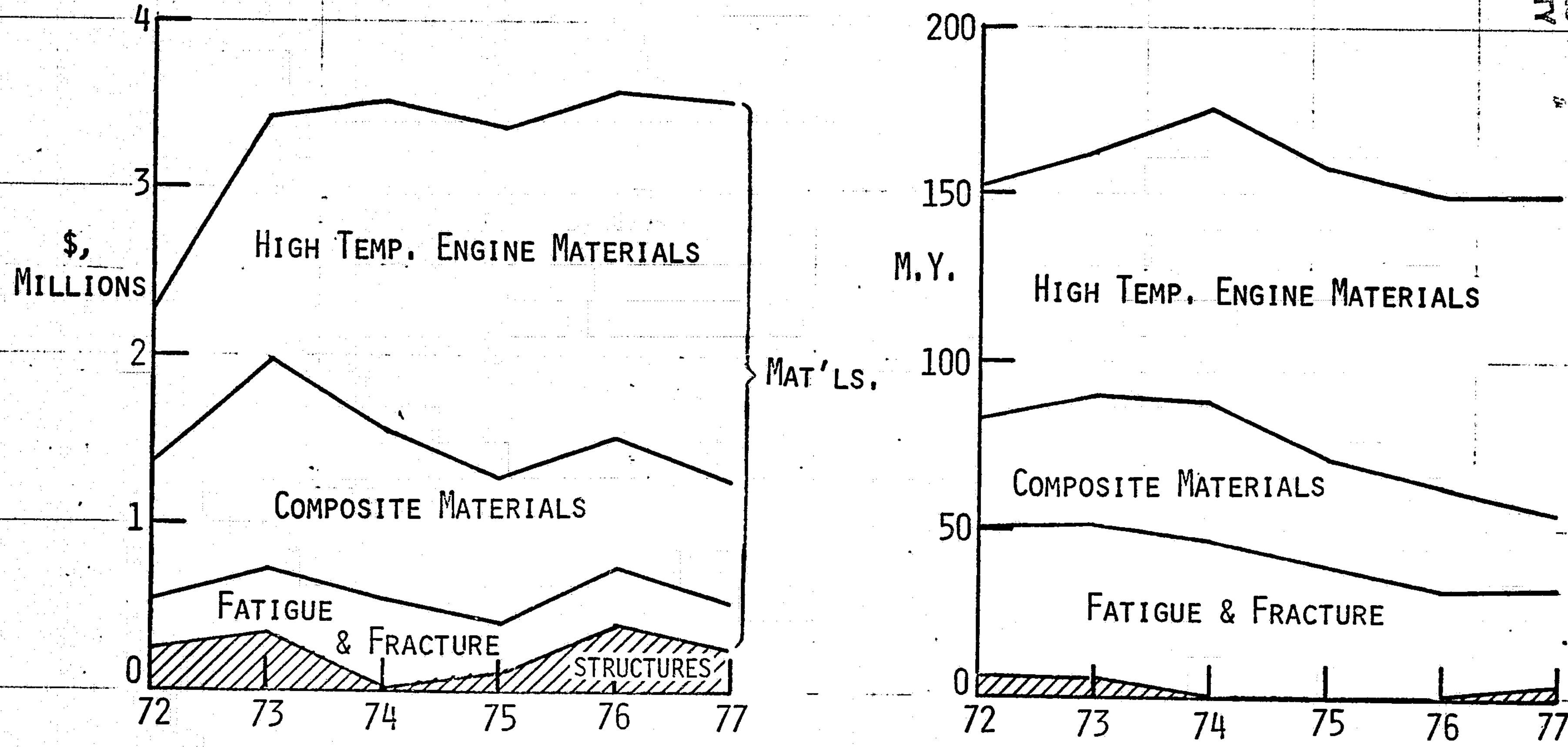
CS-73101

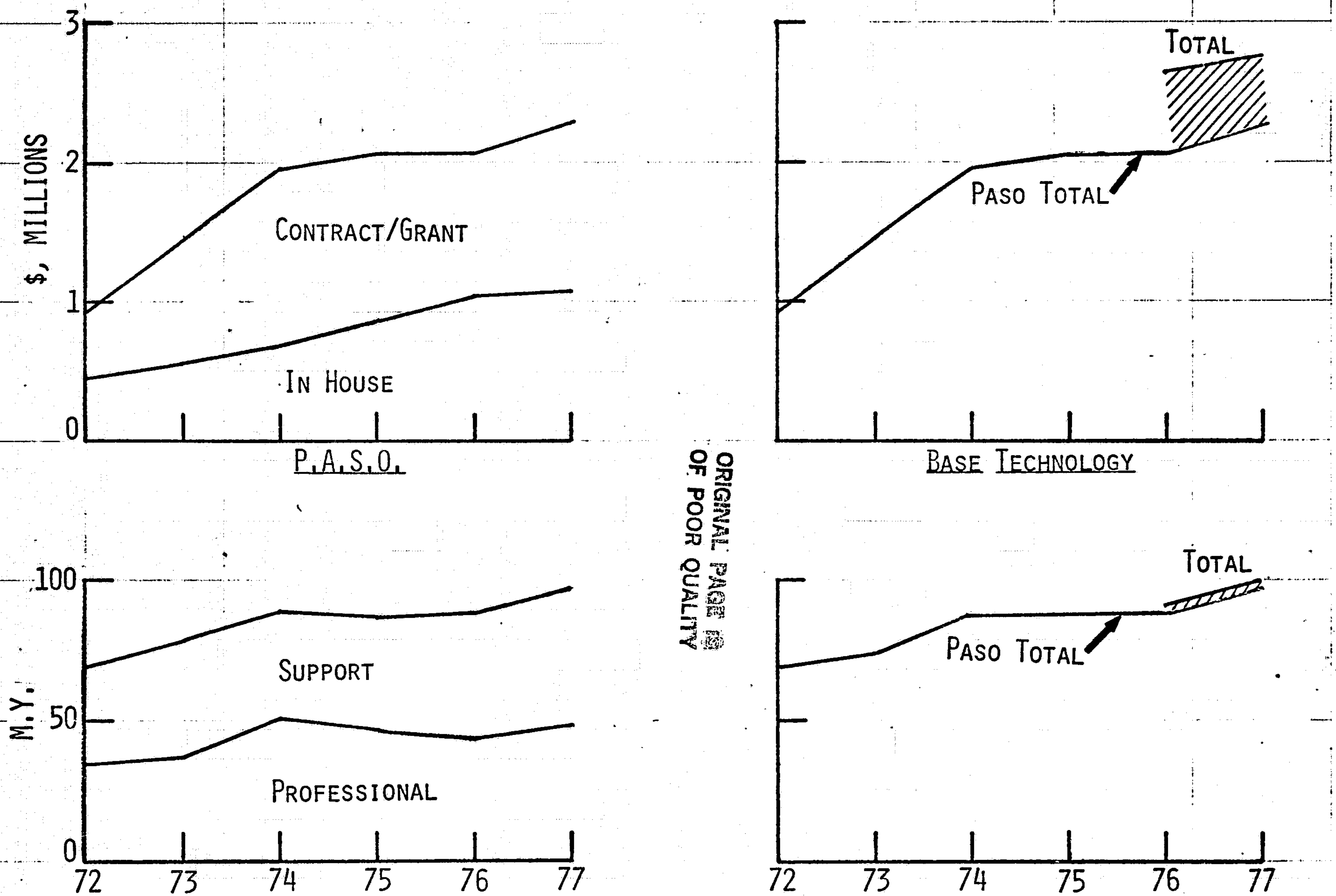
R & T TRENDS

MATERIALS & STRUCTURES



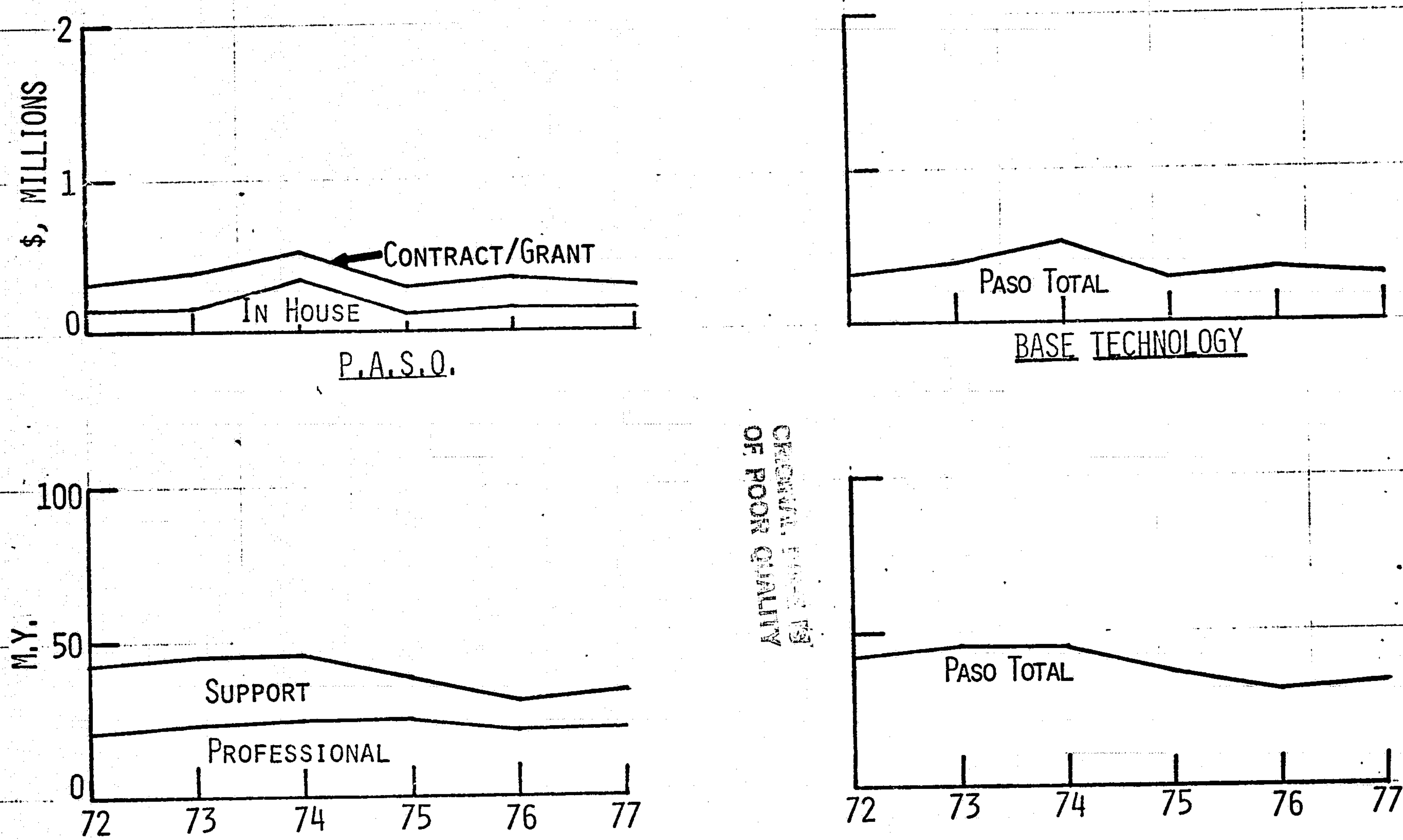
R & T TRENDS

HIGH TEMPERATURE ENGINE MATERIALS



R & T TRENDS

FATIGUE, FRACTURE & LIFE PREDICTION



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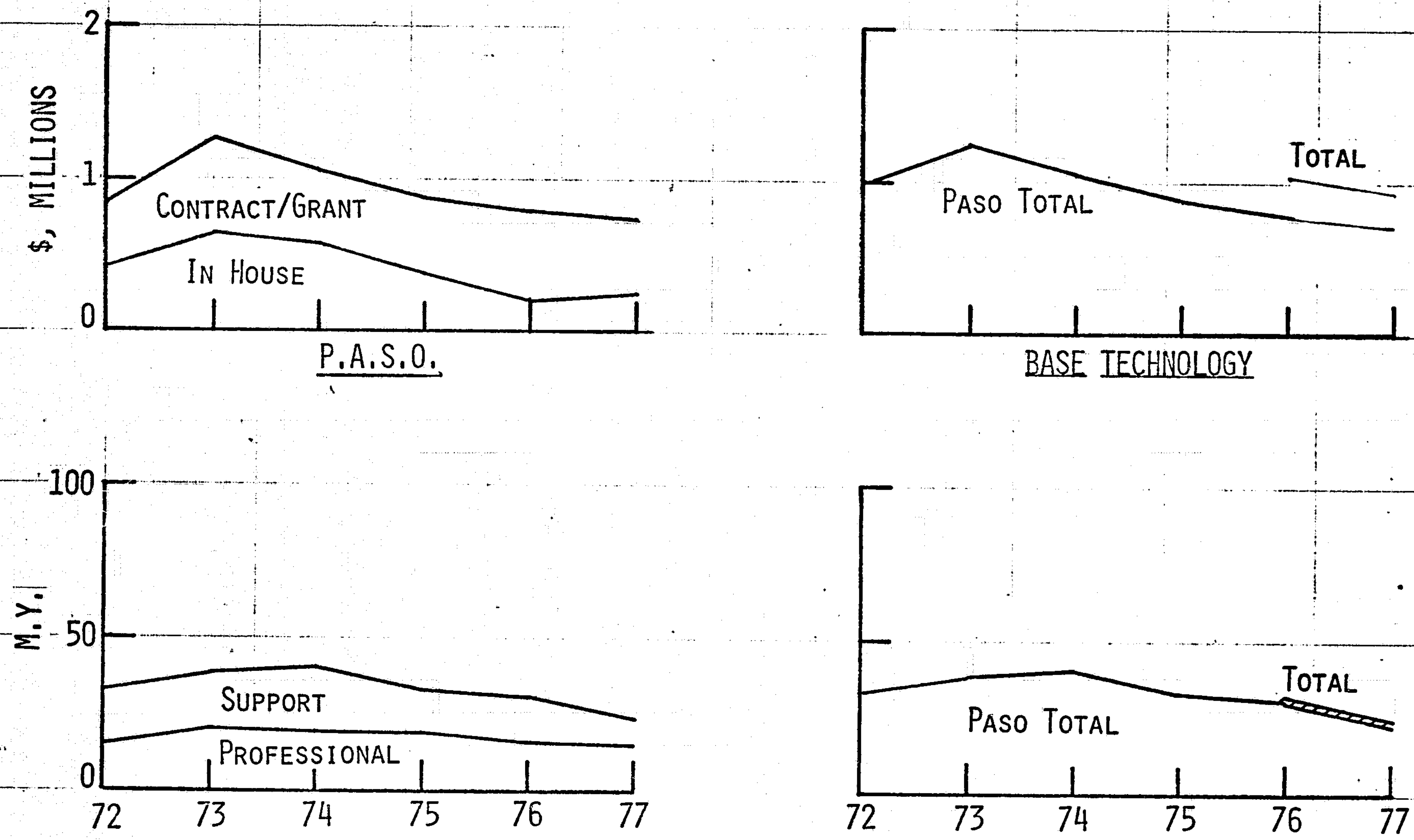
R & T TRENDS

SAFER LIGHTWEIGHT AIRCRAFT MATERIALS
(COMPOSITE MATERIALS)



NASA - LEWIS HIGH TEMPERATURE ENGINE

MATERIALS PROGRAM

Bert Probst
March 16, 1977

HIGH TEMPERATURE ENGINE MATERIALS

R&T BASE

OBJECTIVE: TO DEVELOP TECHNOLOGY BASE TO PROVIDE SUPERIOR MATERIALS & PROCESSES FOR THE HIGH TEMPERATURE COMPONENTS OF AIRCRAFT TURBINE ENGINES.

MAJOR TARGETS:

- IDENTIFY IMPROVED BLADE MATERIAL BY FY 78
- UNCOATED OXIDE DISPERSION STRENGTHENED VANE FOR 2000°F/ 3000 HOURS AND 25% LOWER COST BY FY 78
- POWDER METALLURGY DISK ALLOY - 1400°F/40% LOWER COST BY FY 80
- CERAMIC SHROUD FOR 2600°F BY FY 80
- THERMAL BARRIER COATINGS 3000 HOUR LIFE FOR BLADES, VANES, AND COMBUSTORS BY FY 80
- FIVE FOLD INCREASE IN BALLISTIC IMPACT RESISTANCE OF SiC AND/ OR Si_3N_4 BY FY 79

HIGH TEMPERATURE ENGINE MATERIALS -- PROGRAM MAJOR THRUSTS

COMPONENT	KEY PROBLEMS	OUR APPROACH	MATERIAL CANDIDATES
BLADES	o STABILITY OF STRENGTHENING PHASES	o ALIGNED MICROSTRUCTURES o INERT STRENGTHENERS o COMBINED STRENGTHENING MECHANISMS	o FIBER REINFORCED SUPERALLOYS o EUTECTICS o ODS + γ' o THERMAL BARRIER COATINGS
VANES	o SURFACE STABILITY o HOT SPOT CAPABILITY	o SEPARATE STRENGTHENING MECHANISM FROM ALLOY CHEMISTRY o ADJUST ALLOY CHEMISTRY FOR CORROSION RESIST	o ODS NiCrAl o CERAMICS o THERMAL BARRIER COATINGS

HIGH TEMPERATURE ENGINE MATERIALS -- PROGRAM MAJOR THRUSTS

COMPONENT	KEY PROBLEMS	OUR APPROACH	MATERIAL CANDIDATES
DISKS	o STRENGTH VS. FABRICABILITY o CRACK NUCLEATION & GROWTH	o POWDER METALLURGY ALLOYS - DERIVE STRENGTH FROM CHEMISTRY NOT DEFORMATION o CREEP-FATIGUE STUDIES	o II B SERIES (HIGH γ'; HIGH REF. METALS)
SHROUDS	o SURFACE STABILITY o ABRADABILITY FOR MINIMUM TIP CLEARANCE	o CORROSION/EROSION RESISTANT MAT'LS o "COMPLIANT" RESPONSE TO TIP RUB	o NiCrAlY o CERAMICS

SOME CONTRIBUTIONS FROM THE HIGH TEMPERATURE ENGINE MATERIALS PROGRAM

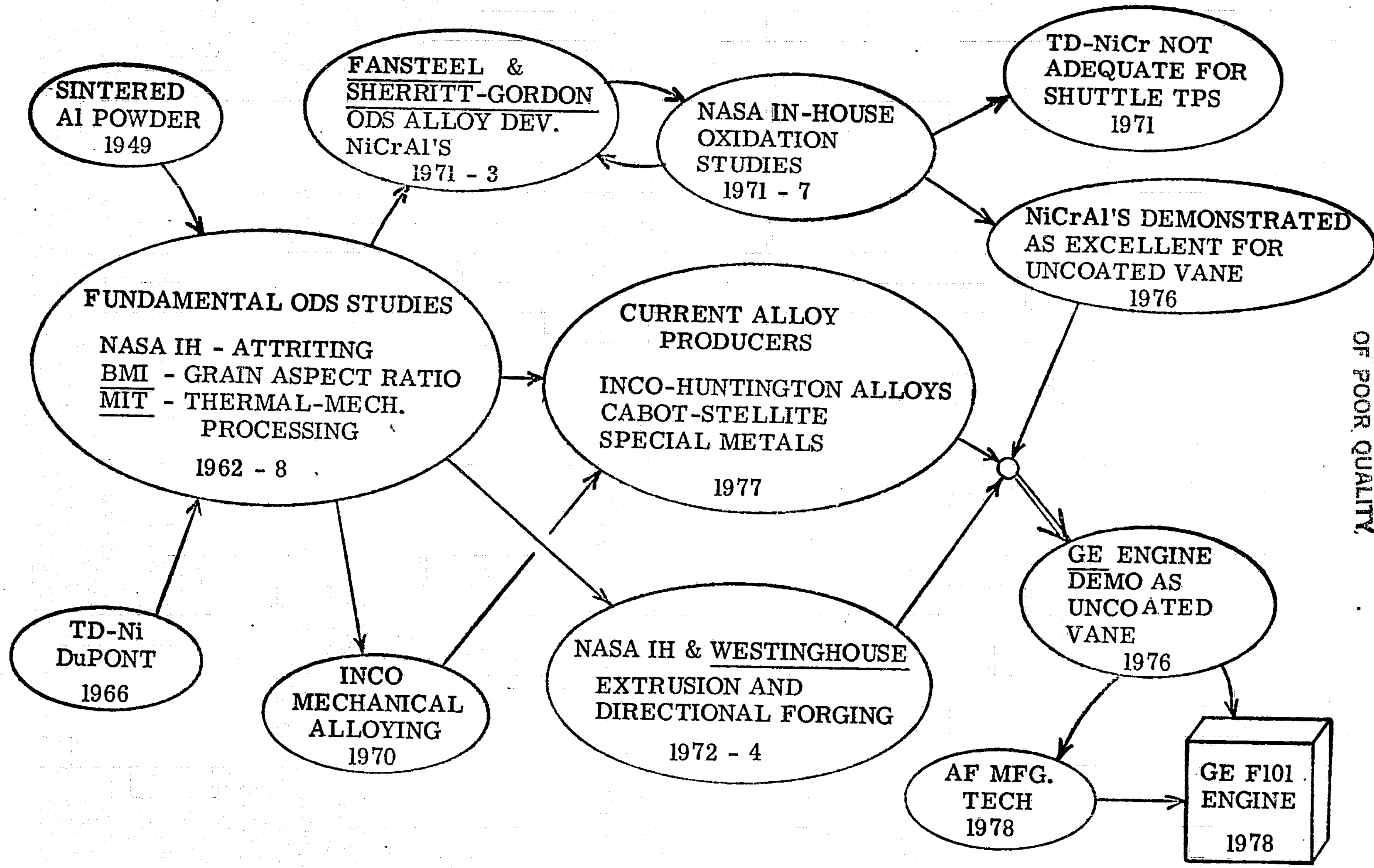
- ODS-NiCrAl VANES
- $\gamma/\gamma'-\delta$ EUTECTIC BLADES
- NiCrAlY SHROUD
- CERAMIC BLADE ROOT - DESIGN CONCEPTS

IR-100 AWARDS

- FIBER REINFORCED SUPERALLOY - 1968
- FLOATING ZONE FIBER DRAWING - 1972
- WAZ ALLOYS - 1974
- THERMAL BARRIER COATINGS - 1976

ODS ALLOYS APPLIED IN ENGINES

A CASE HISTORY OF NASA-INDUSTRY-UNIVERSITY PARTNERSHIP



UNDERLINES DENOTE NASA SPONSORSHIP

OBJECTIVE: FATIGUE, FRACTURE, & LIFE PREDICTION

505-01-2

M.H. HIRSCHBERG

TARGETS

- VERIFY STRAINRANGE PARTITIONING FOR ENGINE COMPONENT LIFE PREDICTION BY FY 81
- DEVELOP ENVIRONMENTALLY CONTROLLED CRACK GROWTH TEST METHODS BY FY 81
- DEVELOP ASTM STANDARD FRACTURE TOUGHNESS TEST METHODS FOR BRITTLE & HIGH-TOUGHNESS MATERIALS

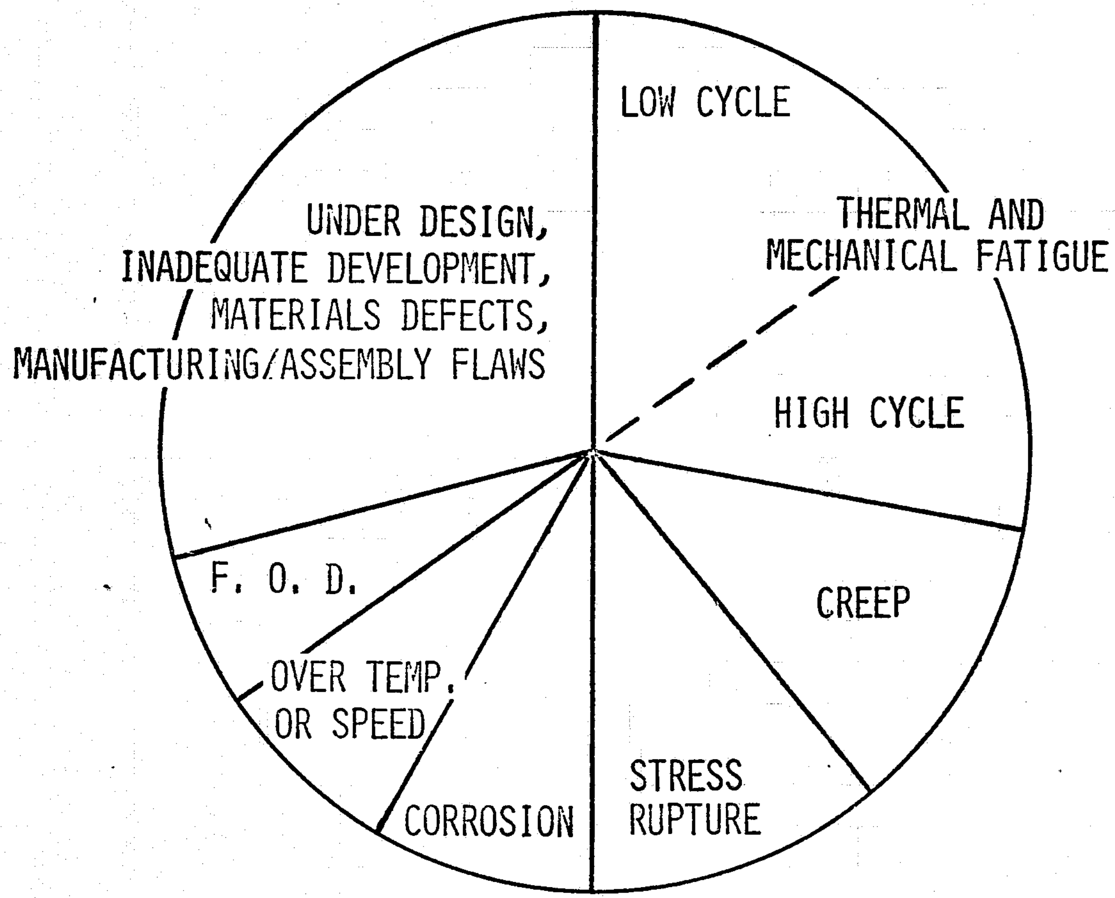
TOTAL R&D $K	300
DMY	29

WHY FATIGUE, FRACTURE, AND LIFE PREDICTION RESEARCH

- MANY BROKEN PARTS AND SERVICE FAILURES
- LARGE NUMBER OF TESTS
  - PROVIDE EMPIRICAL DATA
  - PROVE AD HOC DESIGNS
- POORLY ORGANIZED DESIGN RATIONALE
- TREMENDOUS ANNUAL COST
  - OCCASIONAL CATASTROPHE
  - FREQUENT RETROFITS AND DOWN TIME
  - INSPECTION
  - MAJOR PROBLEMS —C-5A, F-111, COMET, 2-0-2

FATIGUE LIFE PREDICTION

CAUSES OF ENGINE FAILURES

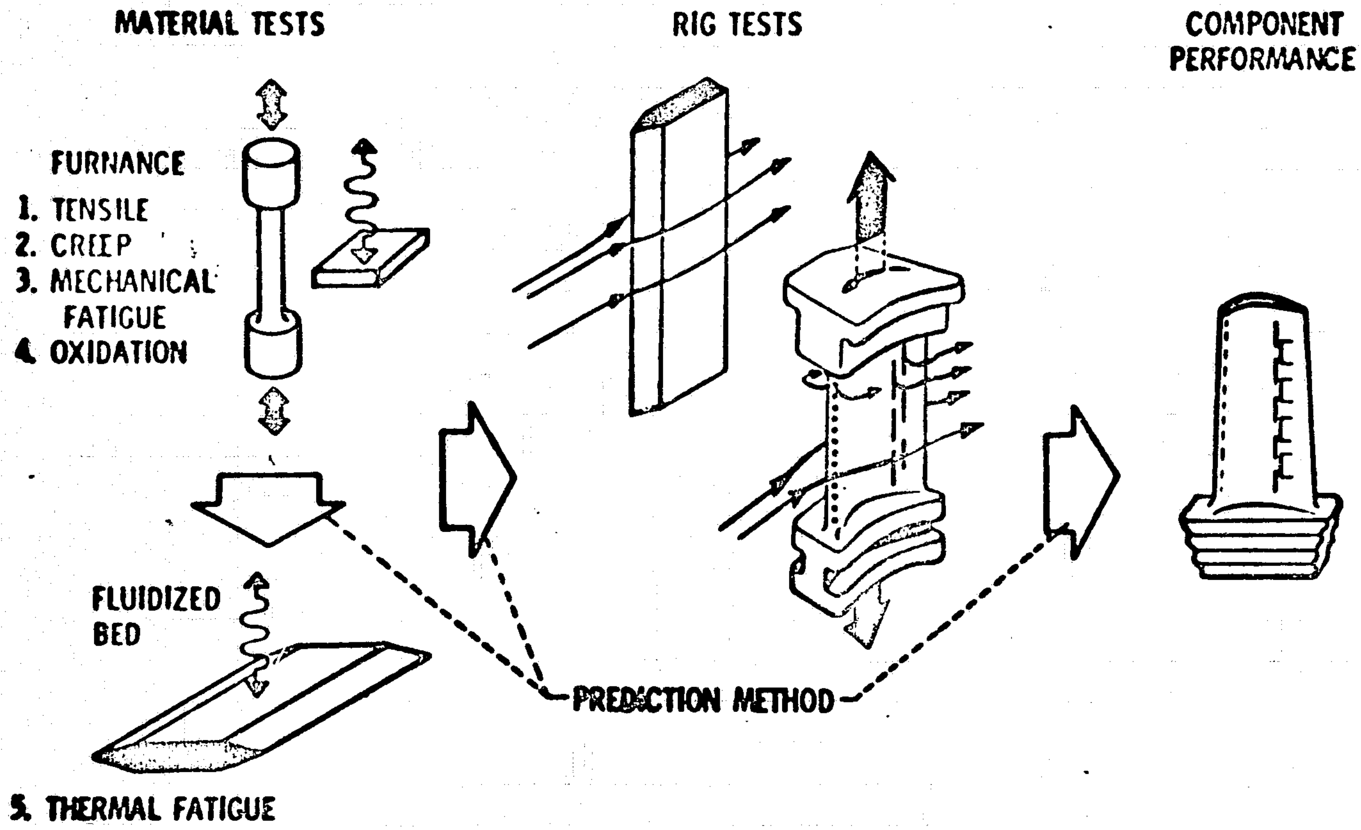


THE HOT ENDS OF THE ENGINES, PRIMARILY THE TURBINE, ARE RESPONSIBLE FOR 70 TO 75 PERCENT OF MAINTENANCE COSTS.

NASA - LEWIS DEVELOPMENTS FOR FATIGUE LIFE PREDICTION

- METHOD OF UNIVERSAL SLOPES - LOW AND INTERMEDIATE TEMPERATURES
- 10% RULE - HIGH TEMPERATURES
- TIME-CYCLE FRACTIONS - HIGH TEMPERATURES
- STRAINRANGE PARTITIONING - HIGH TEMPERATURES

TURBINE COMPONENT LIFE PREDICTION PROGRAM



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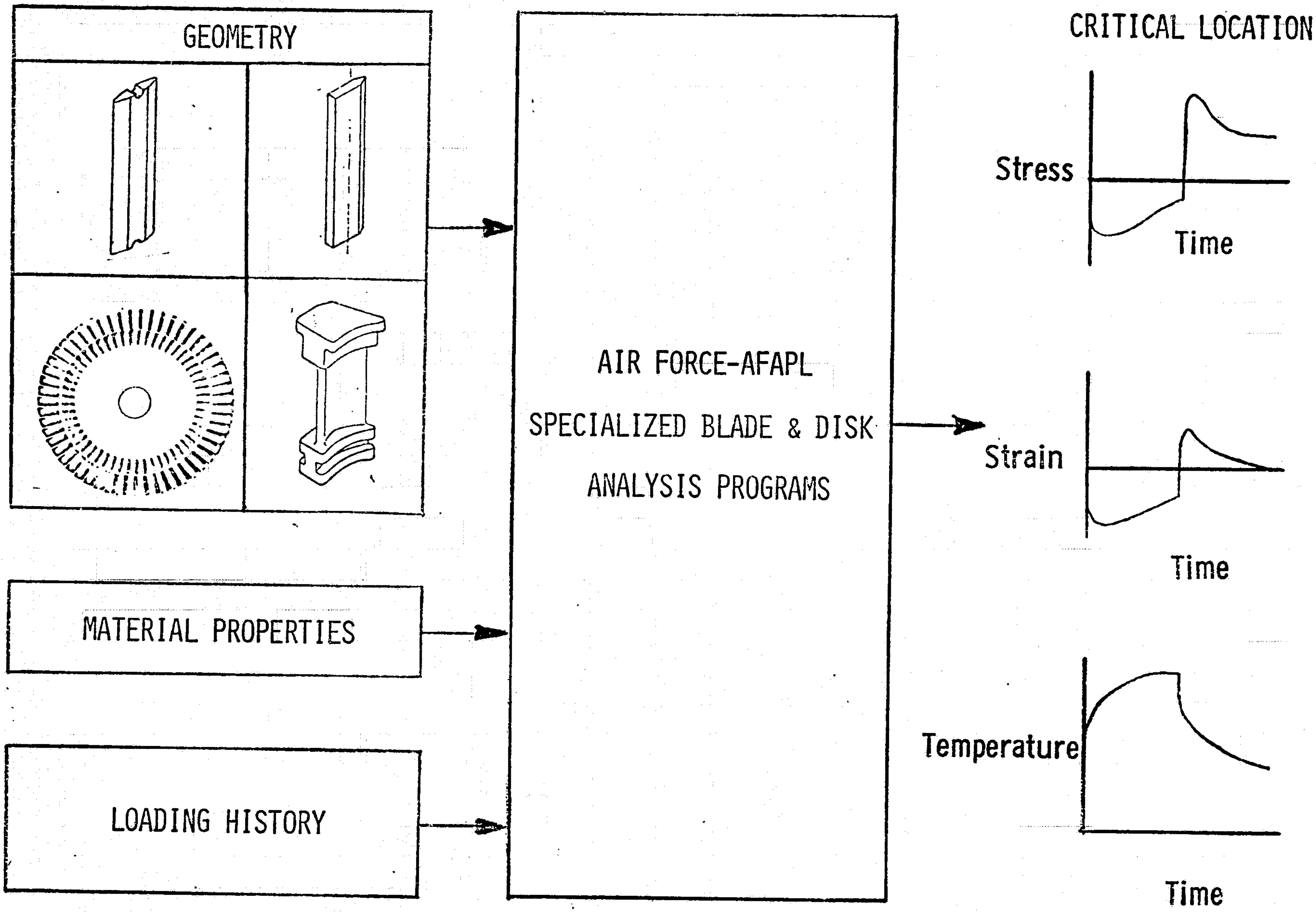
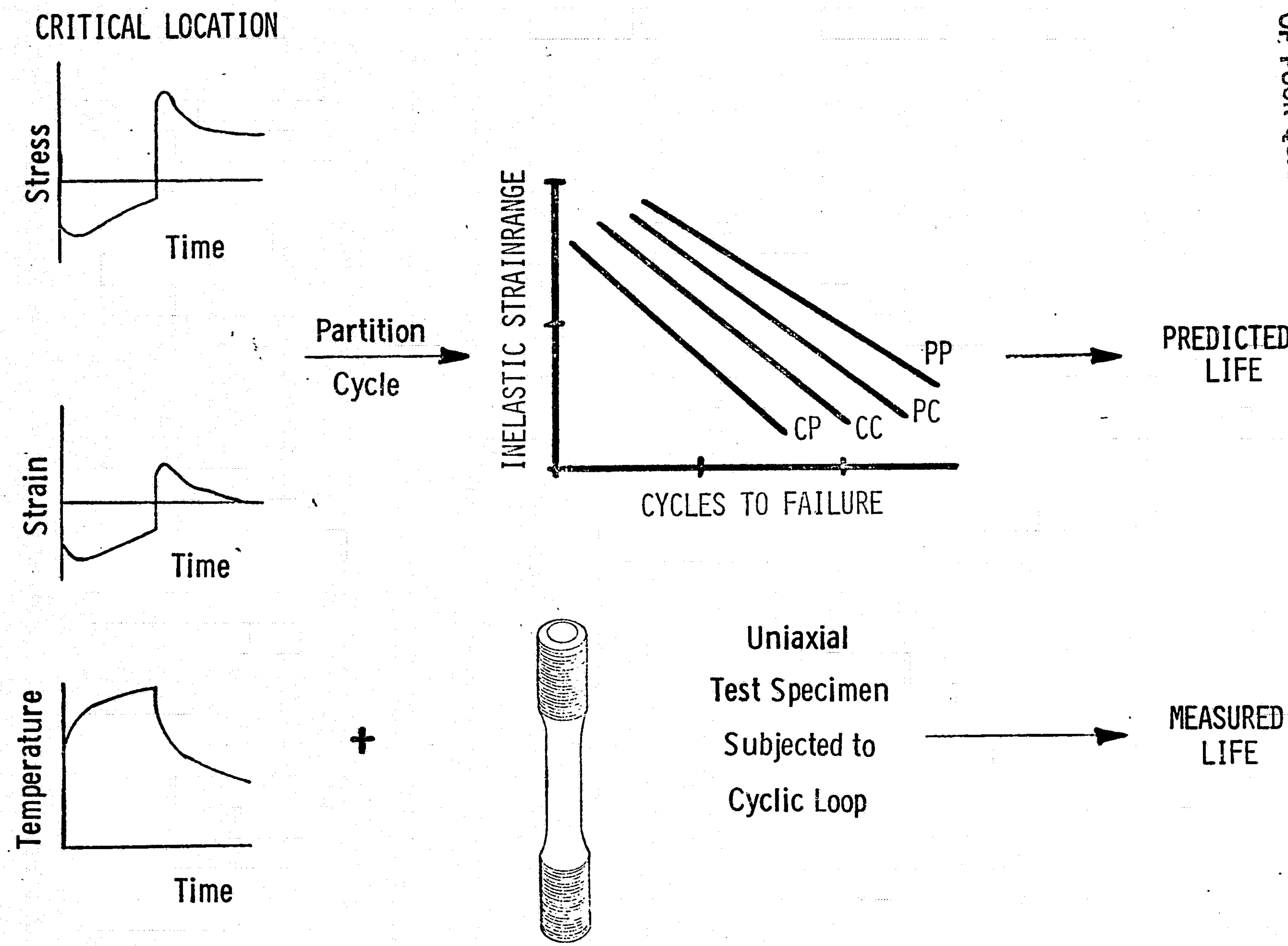
TRANSIENT ANALYSIS FOR LIFE PREDICTION



COMPARISON OF EXPERIMENTAL AND CALCULATED LIVES



AGARD PROGRAM PARTICIPANTS

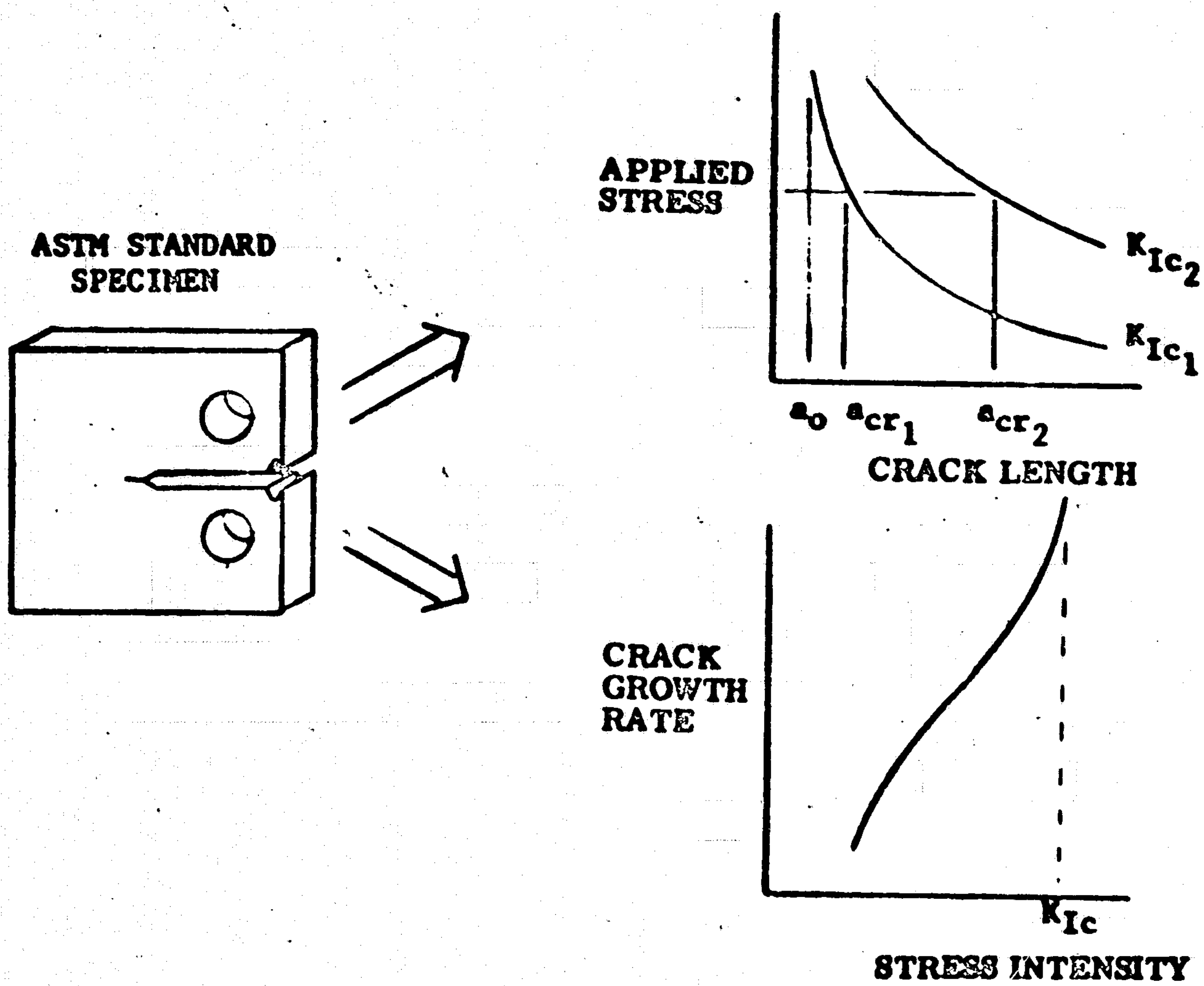
NASA LEWIS	USA	NGTE	GB
GE EVENDALE	"	NPL	"
P&WA FLORIDA	"	ROLLS ROYCE	"
ORNL	"	CRANFIELD TECH	"
AFML	"	UNIV OF BRISTOL	"
TRW CLEVELAND	"	ONERA	F
MAR-TEST	"	CEAT	"
PENN STATE UNIV	"	DFVLR	D
CASE WESTERN RESERVE UNIV	"	IABG OTTOBRUNN	"
		CRM	B

INDUSTRY/GOVERNMENT COMMITTEE ON AIRCRAFT
GAS TURBINE ENGINE COMPONENT LIFE PREDICTION

GOVERNMENT	INDUSTRY
AFAPL	GE
AFML	P&WA
AFOSR	GM-ALLISON
AFFDL	GARRETT
ASD	TELEDYNE CAE
NASA	WILLIAMS RES.
NAPTC	AVCO-LYCOMING
AMRDL	

FRACTURE

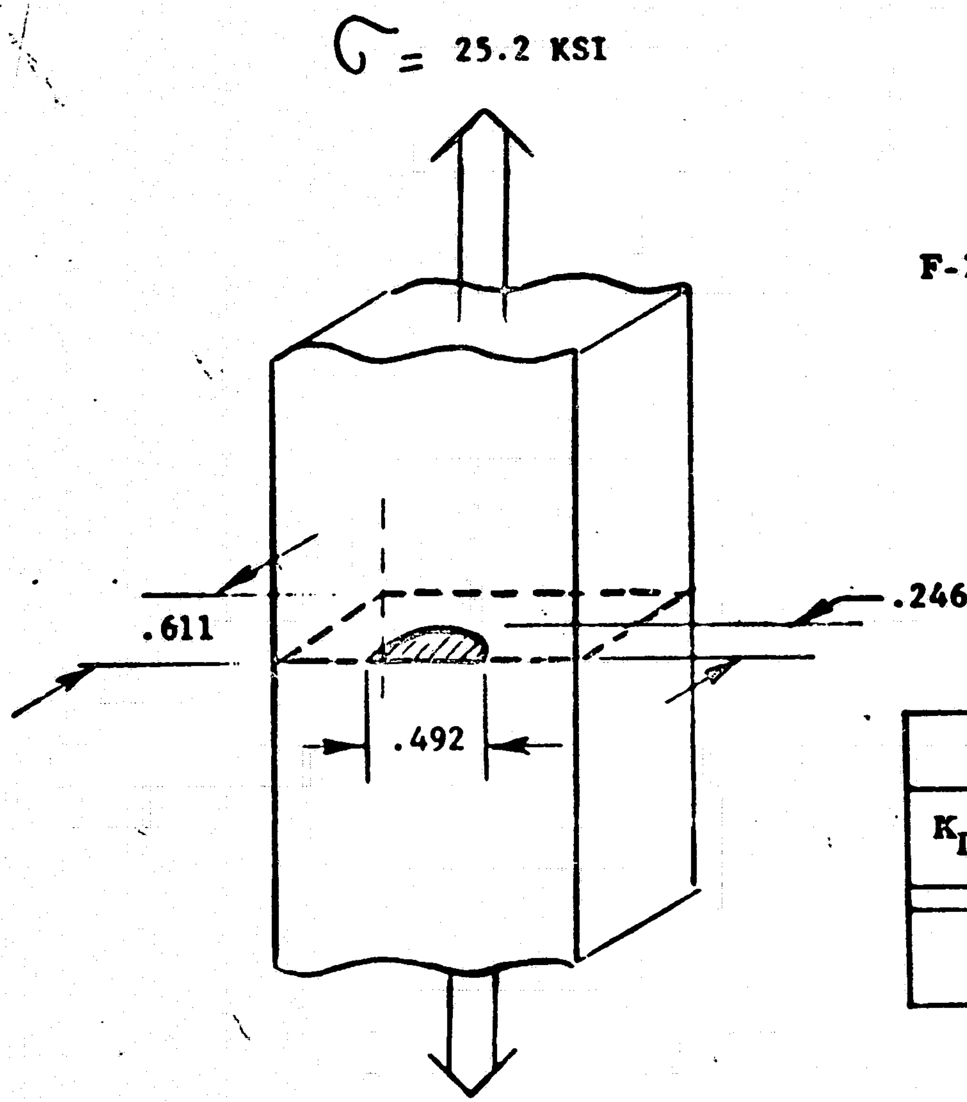
STANDARD TEST METHODS FOR CRACK GROWTH & FRACTURE RESISTANCE MEASUREMENTS



1. FRACTURE CONTROL PLAN
   (Material Selection, Design, Manufacture, and Operation)

2. FAILURE ANALYSIS & REMEDIAL ACTIONS

EFFECT OF FRACTURE TOUGHNESS ON LIFE



F-111 Baseline Severe Usage
Mid-Point da/dN Data
2024-T851

LIFE INTERVAL IN FLIGHT HOURS		
$K_{IC} = 20$	$K_{IC} = 23$	$K_{IC} = 26$
250	1560	2350

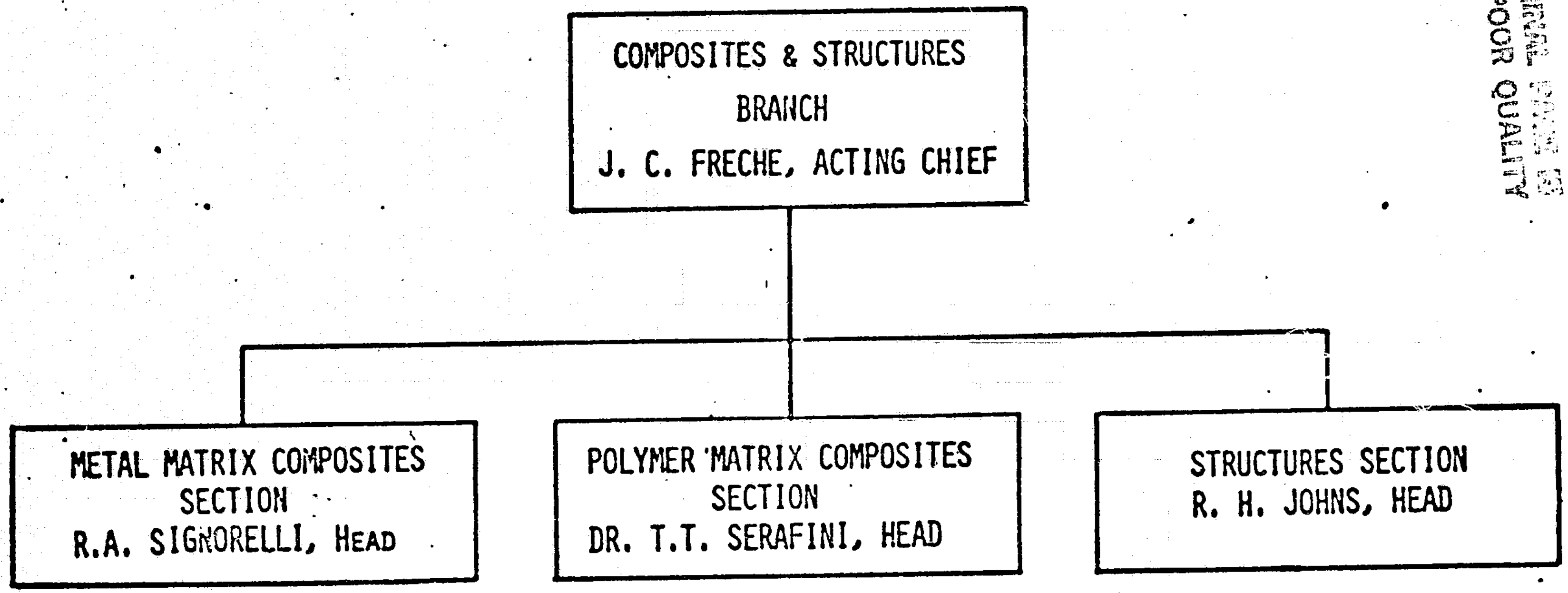
TOUGHNESS IMPROVEMENT DUE TO MICROSTRUCTURAL CONTROL

ALLOY-TEMPER	YIELD STRENGTH	FRACTURE TOUGHNESS
2024-T851	62	22
2124-T851	64	30

COMPOSITES AND STRUCTURES

505-01-3 505-02-4

JOHN C. FRECHE


COMPOSITES & STRUCTURES
BRANCH
J. C. FRECHE, ACTING CHIEF
METAL MATRIX COMPOSITES
SECTION
R.A. SIGNORELLI, HEAD
POLYMER MATRIX COMPOSITES
SECTION
DR. T.T. SERAFINI, HEAD
STRUCTURES SECTION
R. H. JOHNS, HEAD

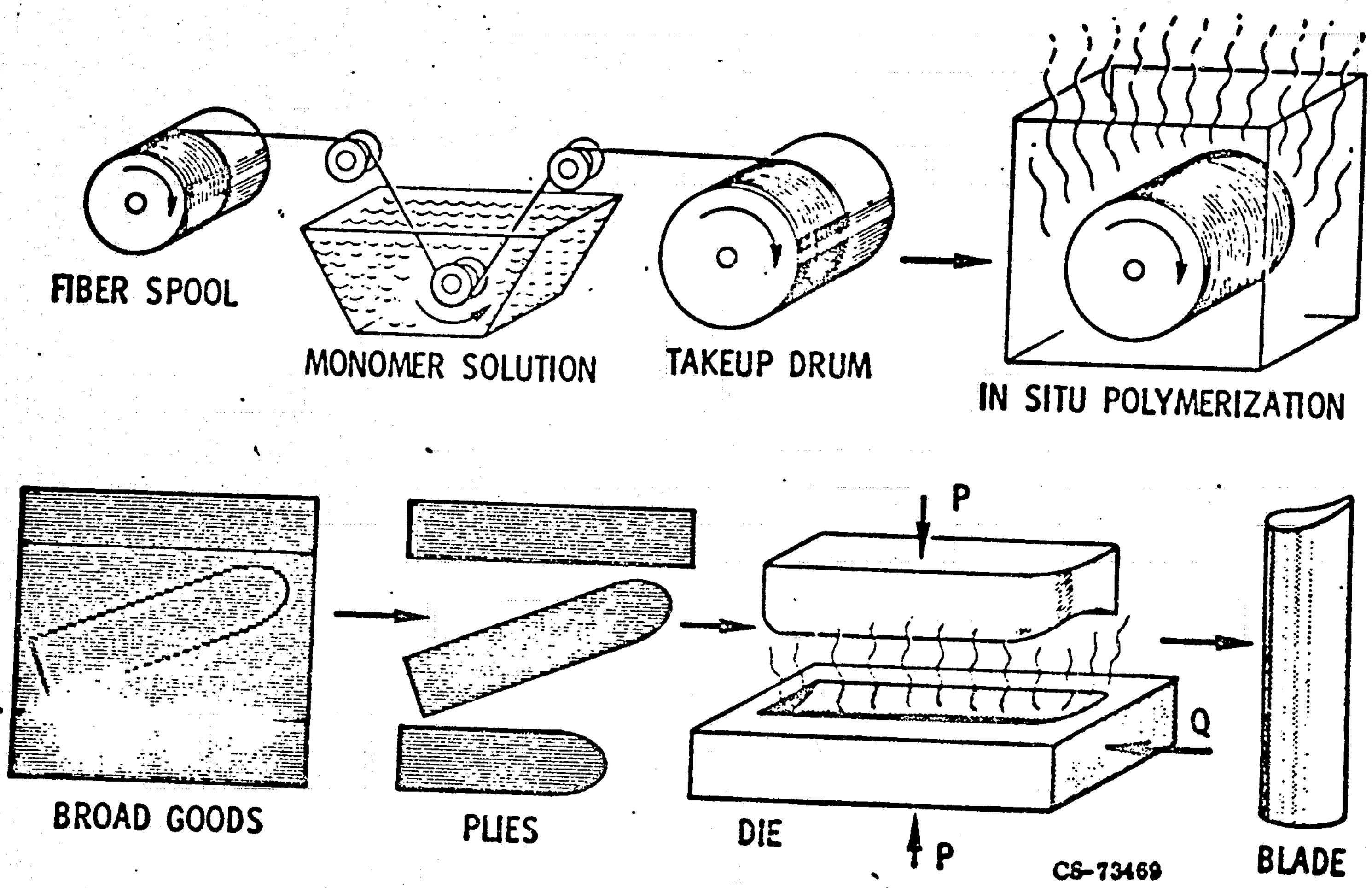
MATERIALS

OBJECTIVE: SAFER LIGHTWEIGHT AIRCRAFT MATERIALS
IMPROVED POLYMERS AND COMPOSITES

- DEVELOP POLYIMIDE GOOD FOR 2000 HRS. AT 600 F BY FY 80
- DEMONSTRATE FILAMENT WOUND COMPOSITE BLADE WITH 25% COST SAVINGS BY FY 80
- DEMONSTRATE FAA FOD REQUIREMENTS FOR COMPOSITE FAN BLADE BY FY 82

	LeRC
TOTAL R&D $M	.7
DMY	22.0

PMR POLYIMIDE PROCESS



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SUPPLIERS OF PMR POLYIMIDE
PREPREG MATERIALS

DuPONT
FERRO
FIBERITE
TRW EQUIPMENT
U. S. POLYMERIC

CURRENT APPLICATIONS OF PMR POLYIMIDES

COMPONENT	CONTRACTOR	AGENCY
QCSEE INNER COWL	GE	NASA LeRC
FOURTH STAGE COMPRESSOR BLADES AND BLADE SPACERS FOR SUPERSONIC WIND TUNNEL AT AEDC	HAMILTON STD.	AIR FORCE
AUGMENTER DUCT FOR F100 ENGINE	COMPOSITES HORIZONS	AIR FORCE
EXTERNAL ENGINE COMPONENTS FOR F100 ENGINE	P&W/TRW	AIR FORCE
YF 12 WING PANELS	IN HOUSE	NASA LaRC
SHUTTLE ORBITER AFT BODY FLAP (CASTS)		NASA LaRC

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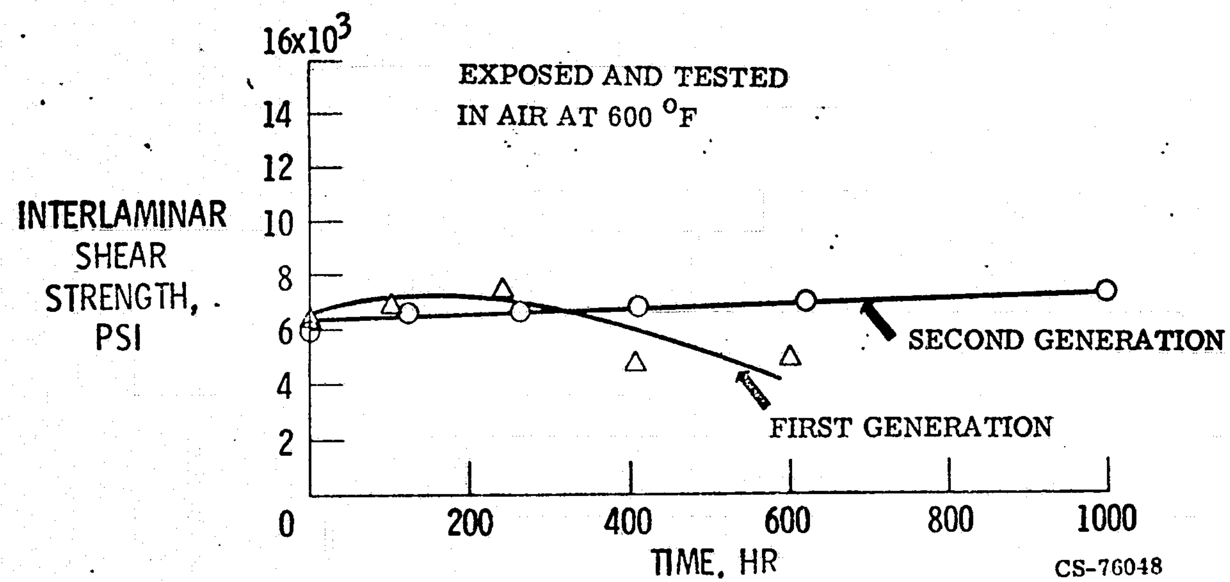
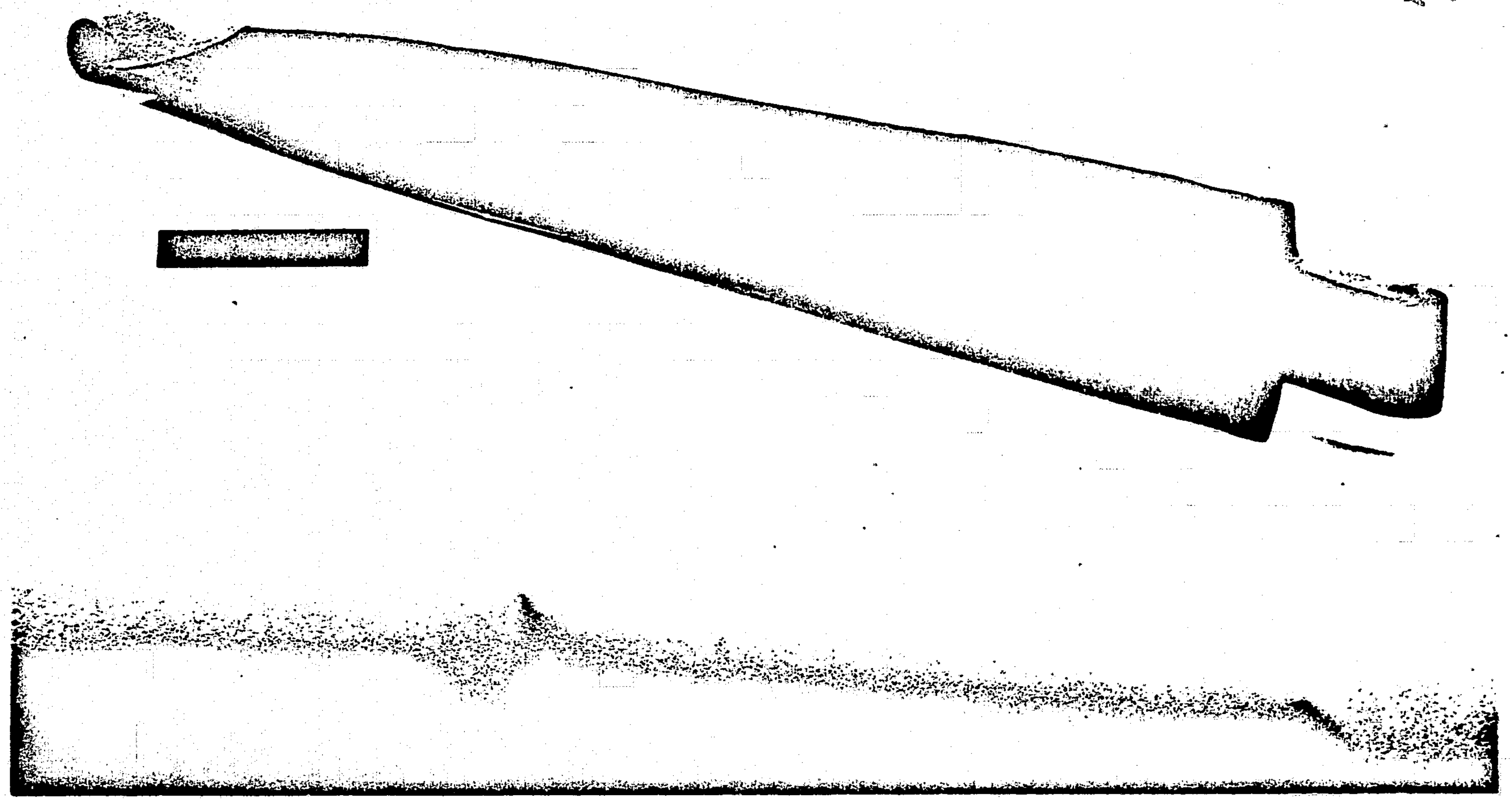
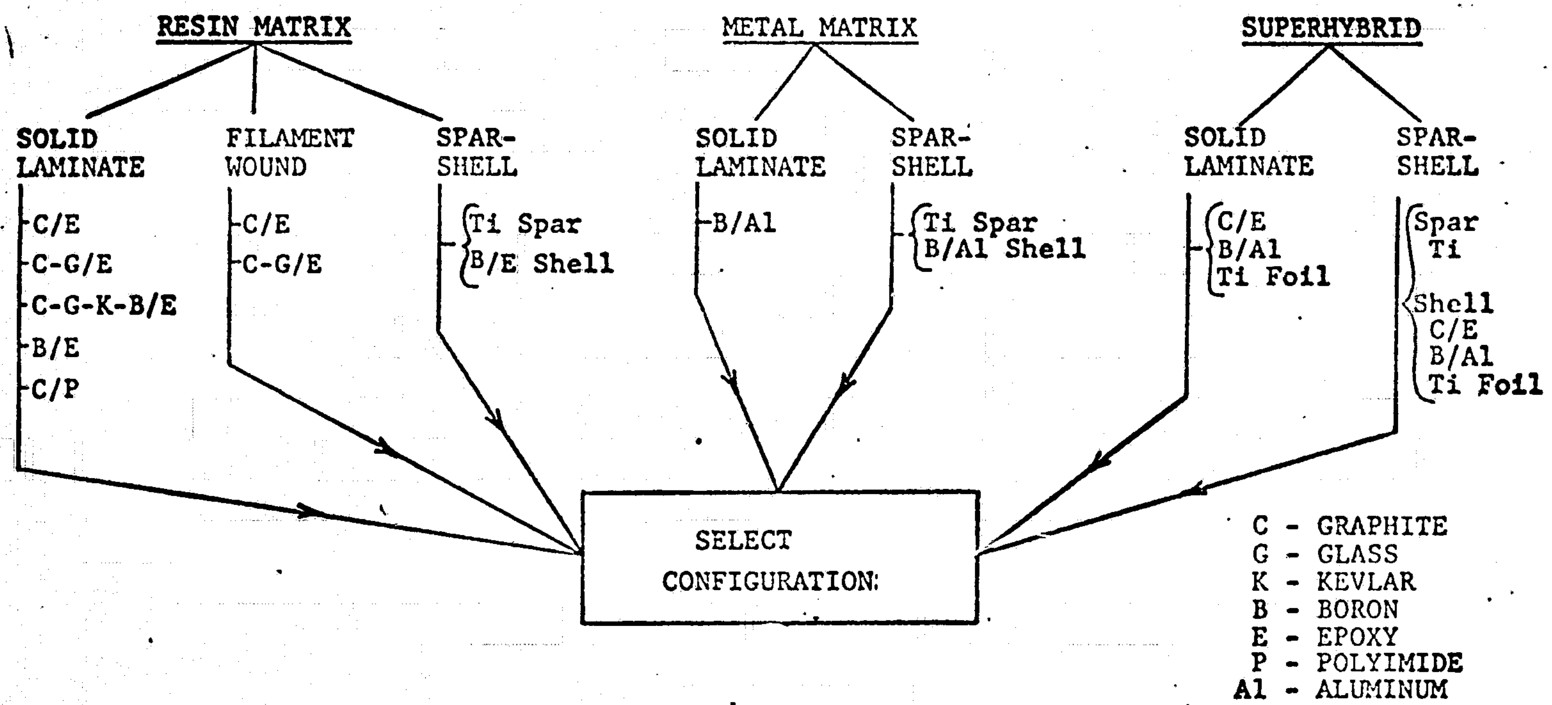
INTERLAMINAR SHEAR STRENGTH OF PMR POLYIMIDE/HTS GRAPHITE FIBER COMPOSITES



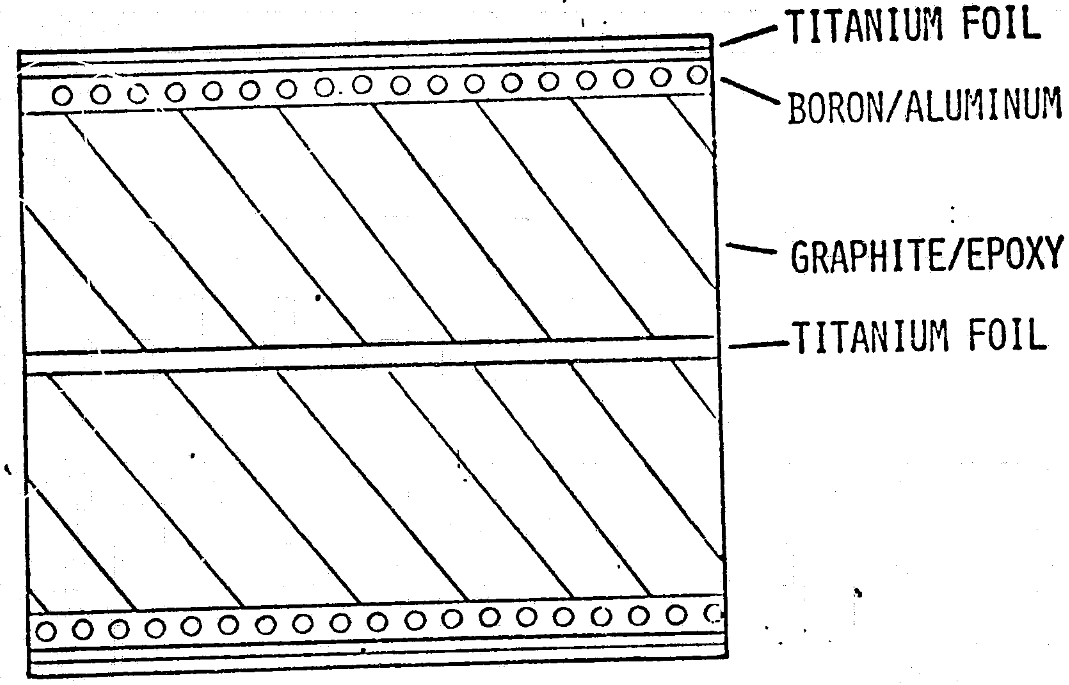
FILAMENT WOUND



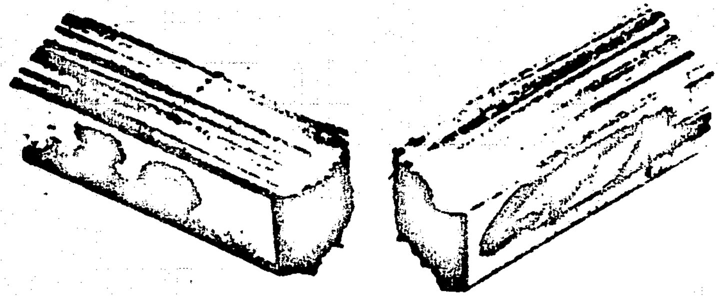
COMPOSITE FAN BLADE PROGRAMS



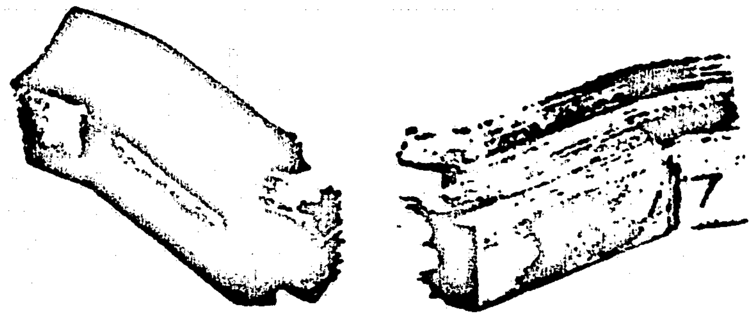
SCHEMATIC OF SUPERHYBRID CONCEPT



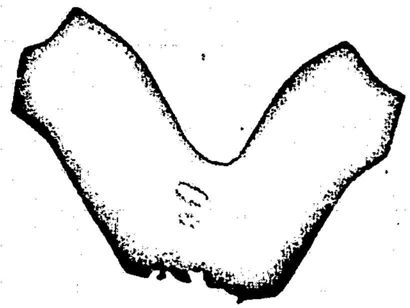
IMPROVED B/AL IMPACT RESISTANCE



18 J (13 FT-LB)
50 V/O 0.14 MM B IN 5052 Al
(UNIDIRECTIONAL)



64 J (47 FT-LB)
50 V/O 0.14 MM B IN 1100 Al
(UNIDIRECTIONAL)

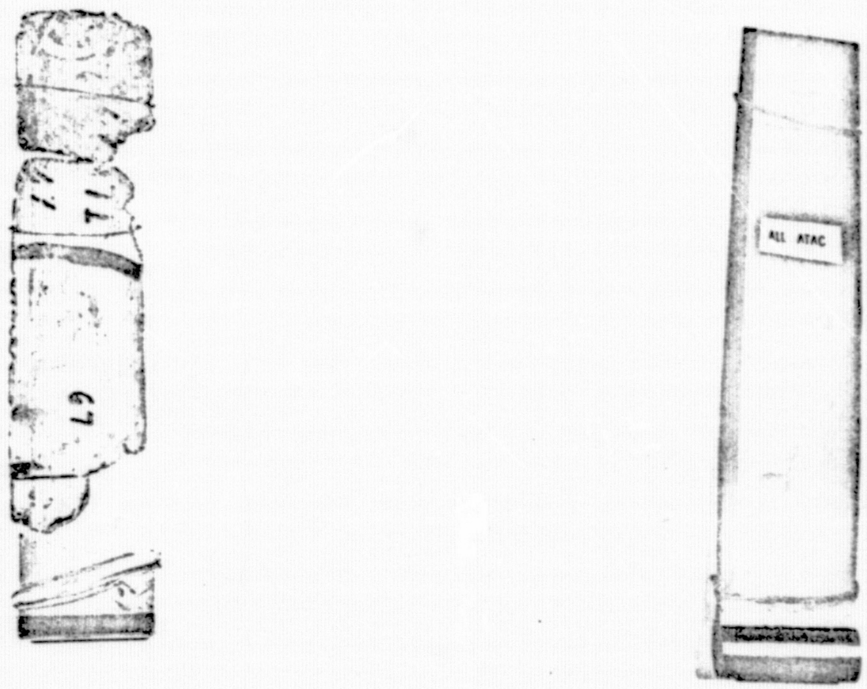


96 J (71 FT-LB)
50 V/O 0.2 MM B IN 1100 Al
(UNIDIRECTIONAL)

CS-72679

IMPROVED FOD TOLERANCE OF B/Al J 79 FAN BLADES

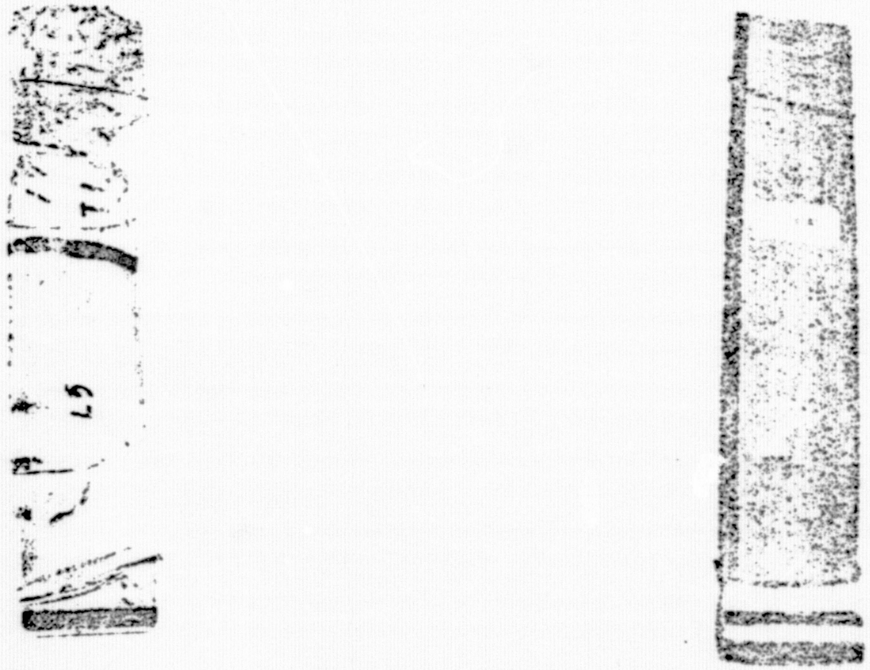
11"



THEN NOW

IMPROVED FOD TOLERANCE OF B/Al J 79 FAN BLADES

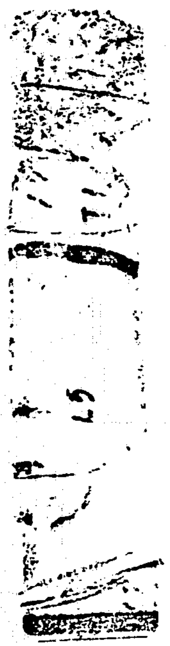
11"



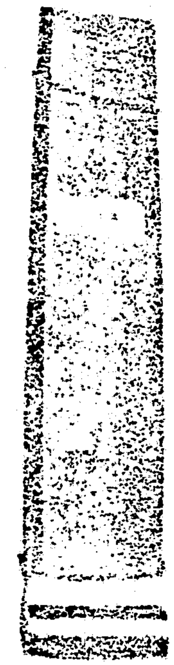
THEN NOW

IMPROVED FOD TOLERANCE OF B/Al J 79 FAN BLADES

11"

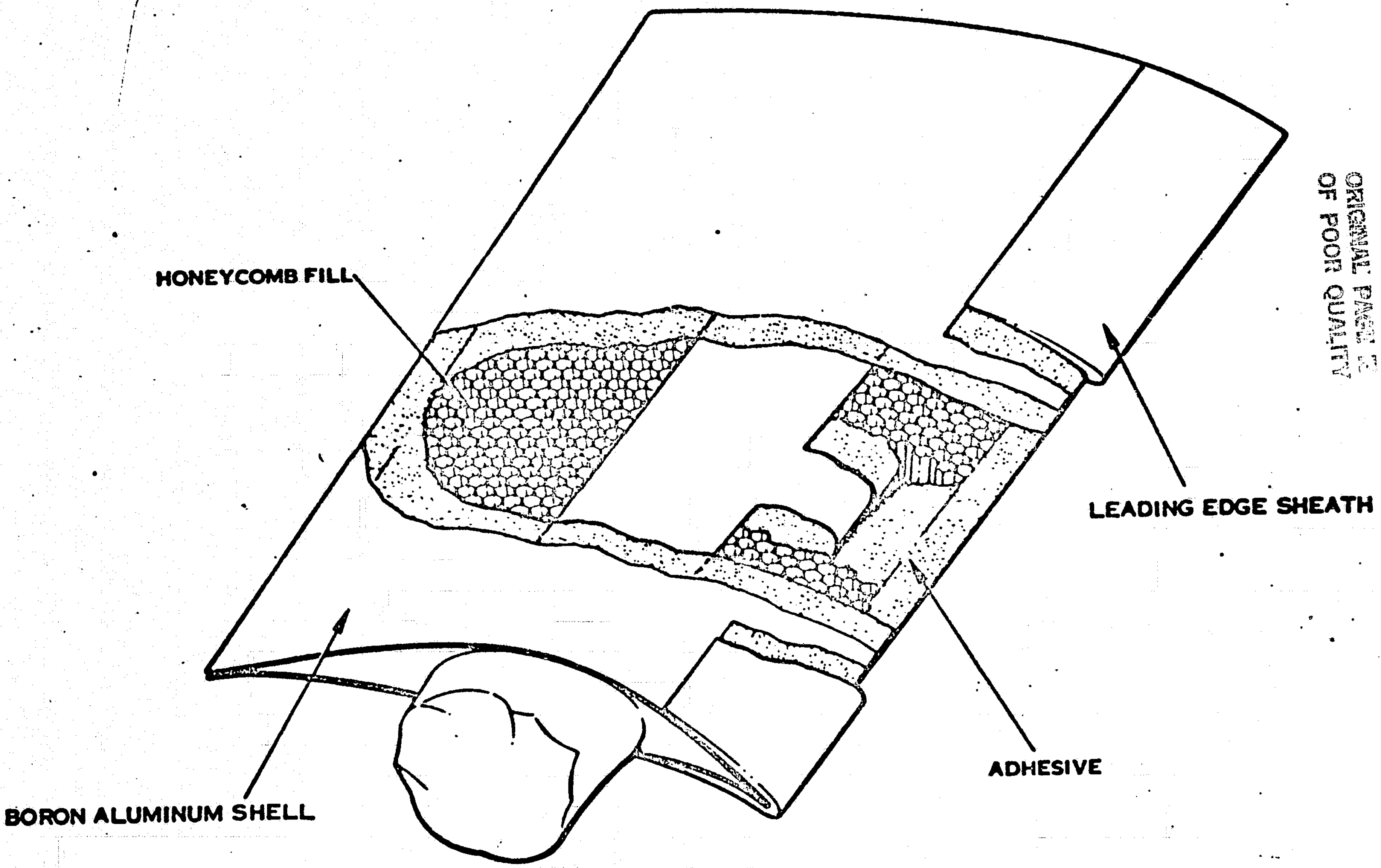


THEN



NOW

QCSEE-TYPE SPAR-SHELL BLADE DESIGN



IMPACTED SPAR SHELL BLADE

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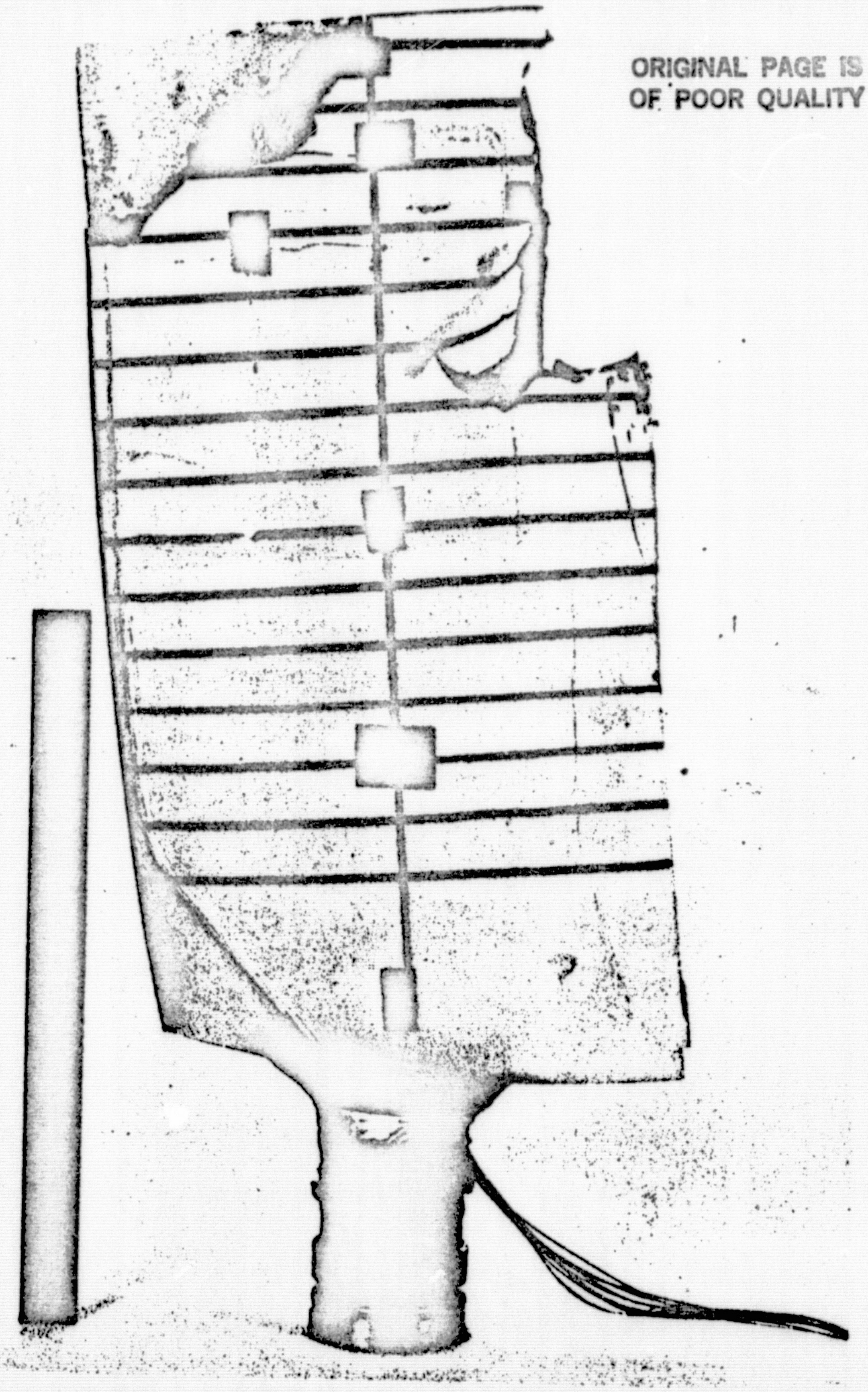


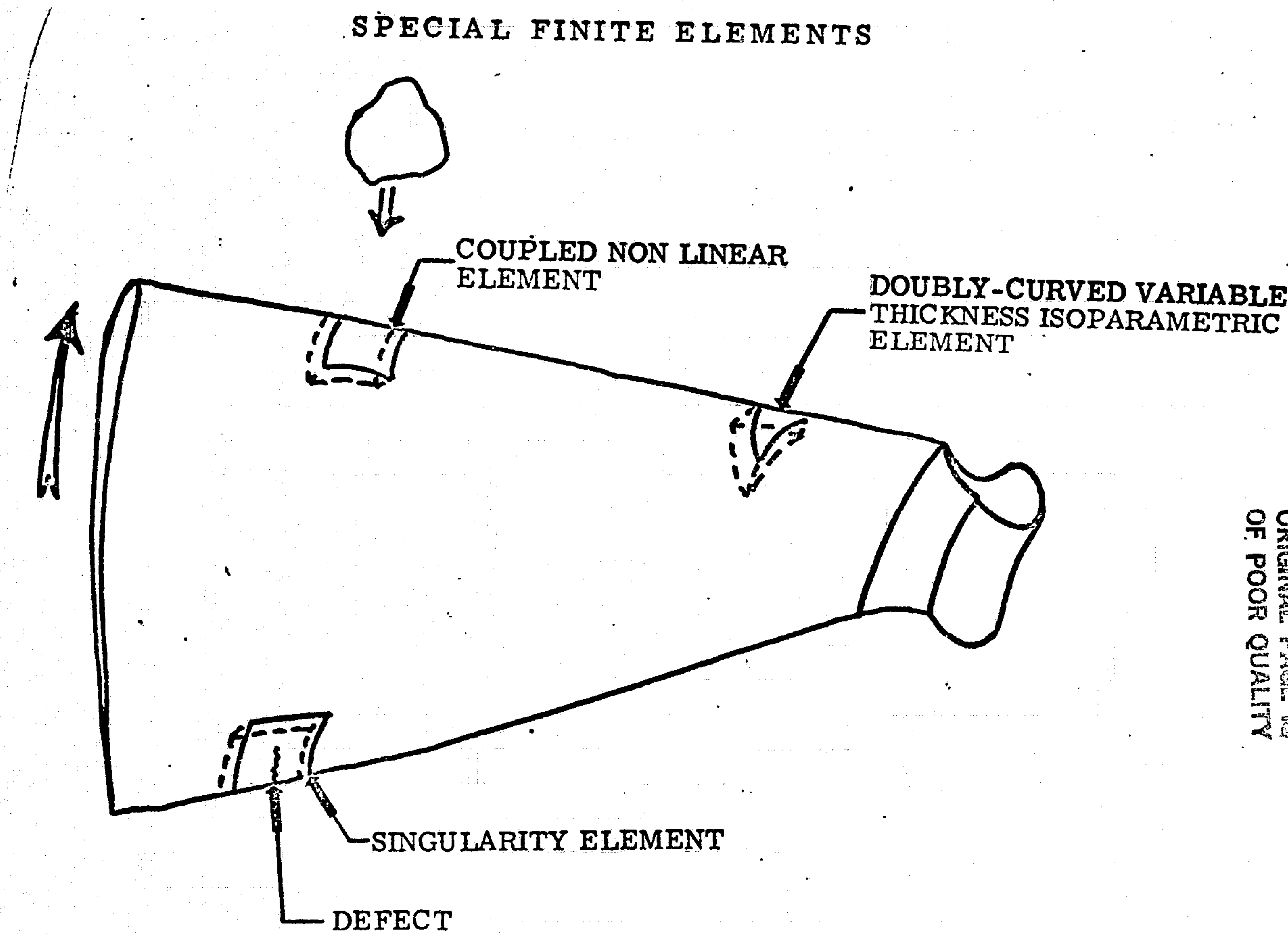
STRUCTURES

OBJECTIVE: ADVANCED AIRCRAFT STRUCTURES
ADVANCED CONCEPTS, INCLUDING COMPOSITES

- DEMONSTRATE 25% WEIGHT REDUCTION FOR STATIC TURBINE COMPOSITE PARTS BY FY 82

	LeRC
TOTAL R&D $M	.2
DMY	3.0

SPECIAL FINITE ELEMENTS



COMPOSITE INTERDEPENDENCY PANEL ACTIVITIES WITH AF

ENGINE FOD

HIGH PERFORMANCE RESIN MATRIX COMPOSITES

ENGINE STATIC STRUCTURES

MOISTURE EFFECTS

AIRFRAME FAILURE MODES

NDI

COMPUTER AIDED DESIGN/ANALYSIS/OPTIMIZATION MODULES FOR COMPOSITES STRUCTURES

ENGINE FLIGHT

ACTIVE COOPERATIVE PROGRAMS WITH AF

J-79

AEROELASTICITY

COOPERATIVE PROGRAMS WITH LaRC

CASTS

PROPULSION ENVIRONMENTAL IMPACT MINIMIZATION

PROPULSION NOISE RESEARCH

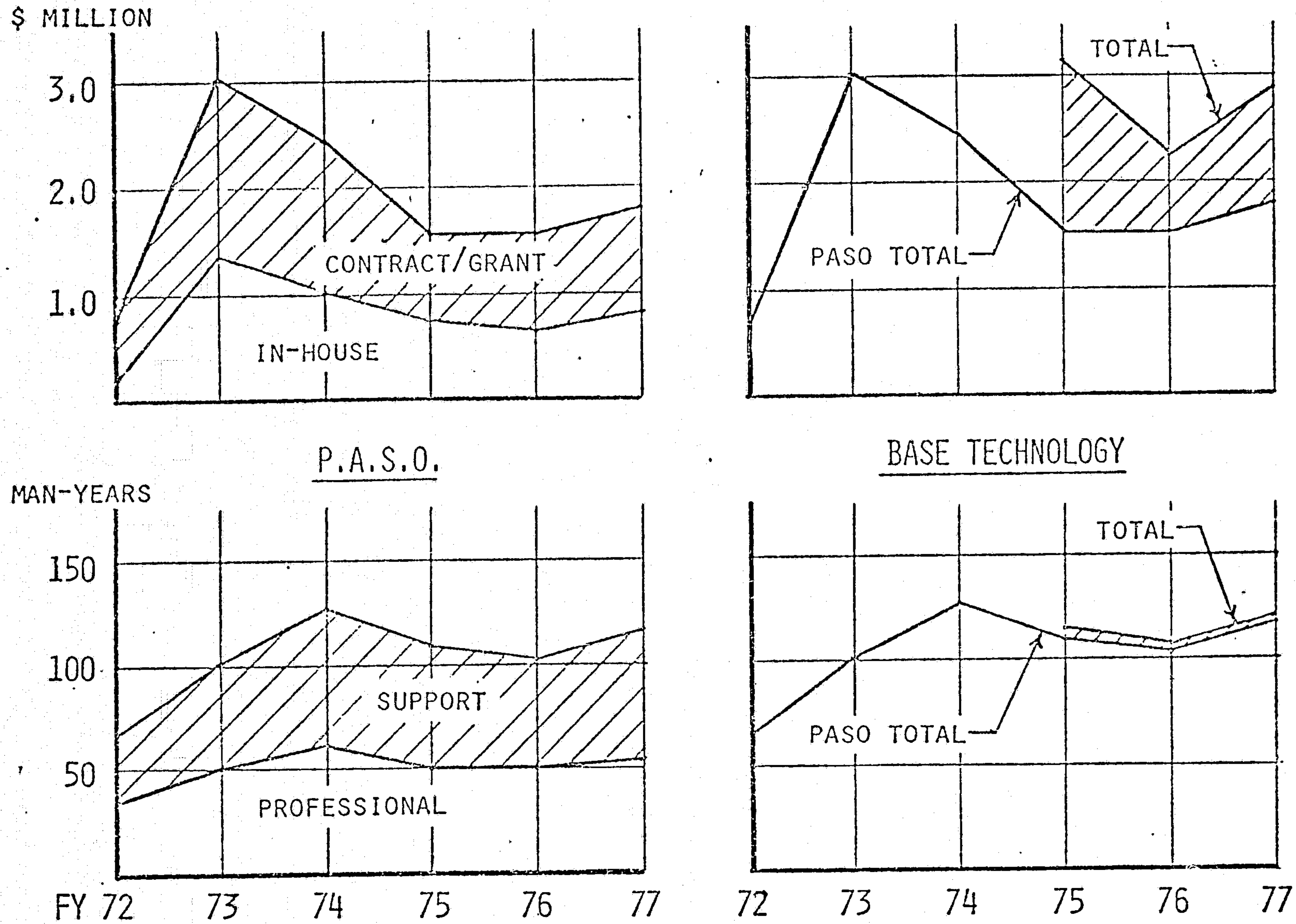
PRESENTER

DR. CHARLES E. FEILER

V/STOL AND NOISE DIVISION

R&T TRENDS

PROPULSION NOISE RESEARCH



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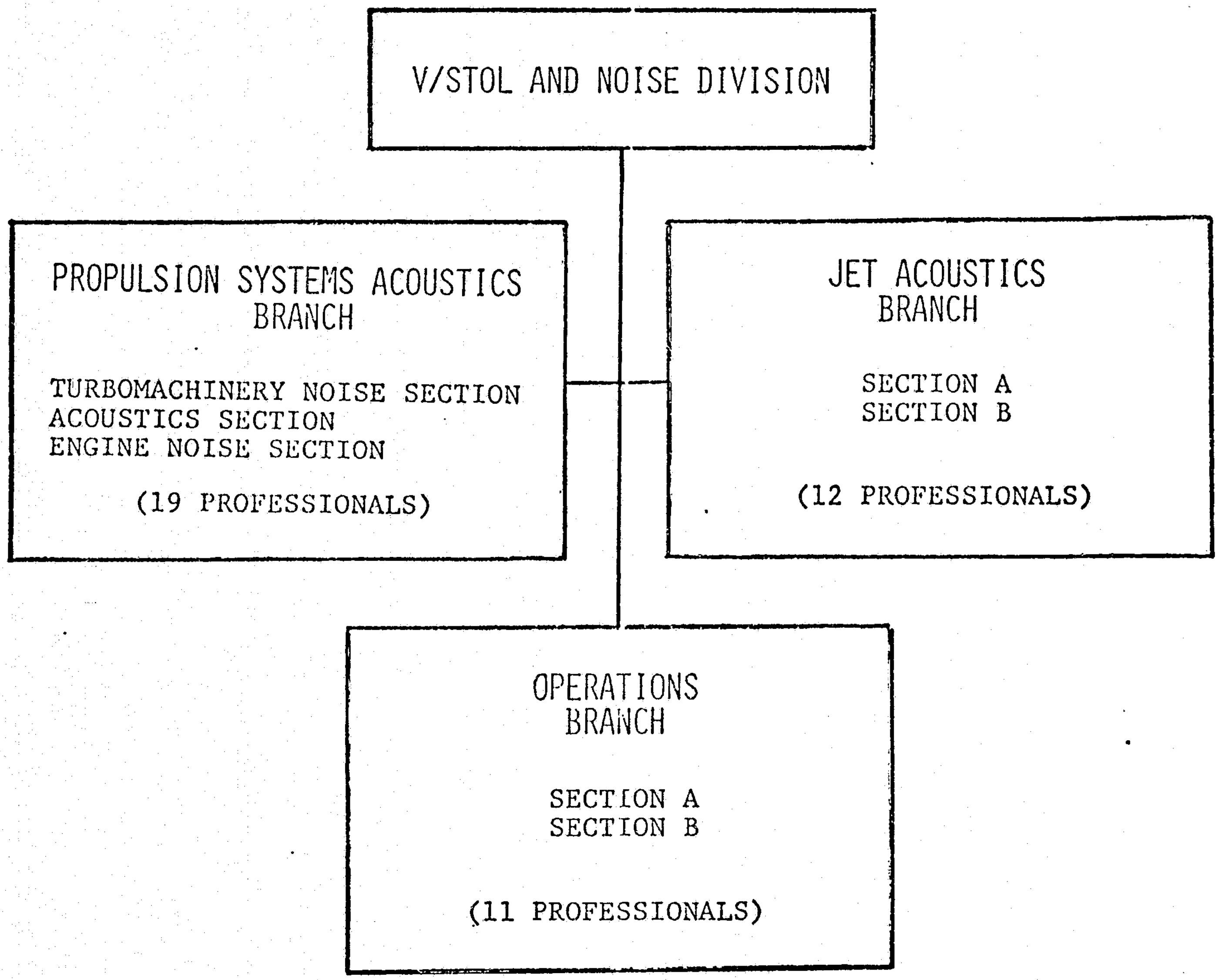
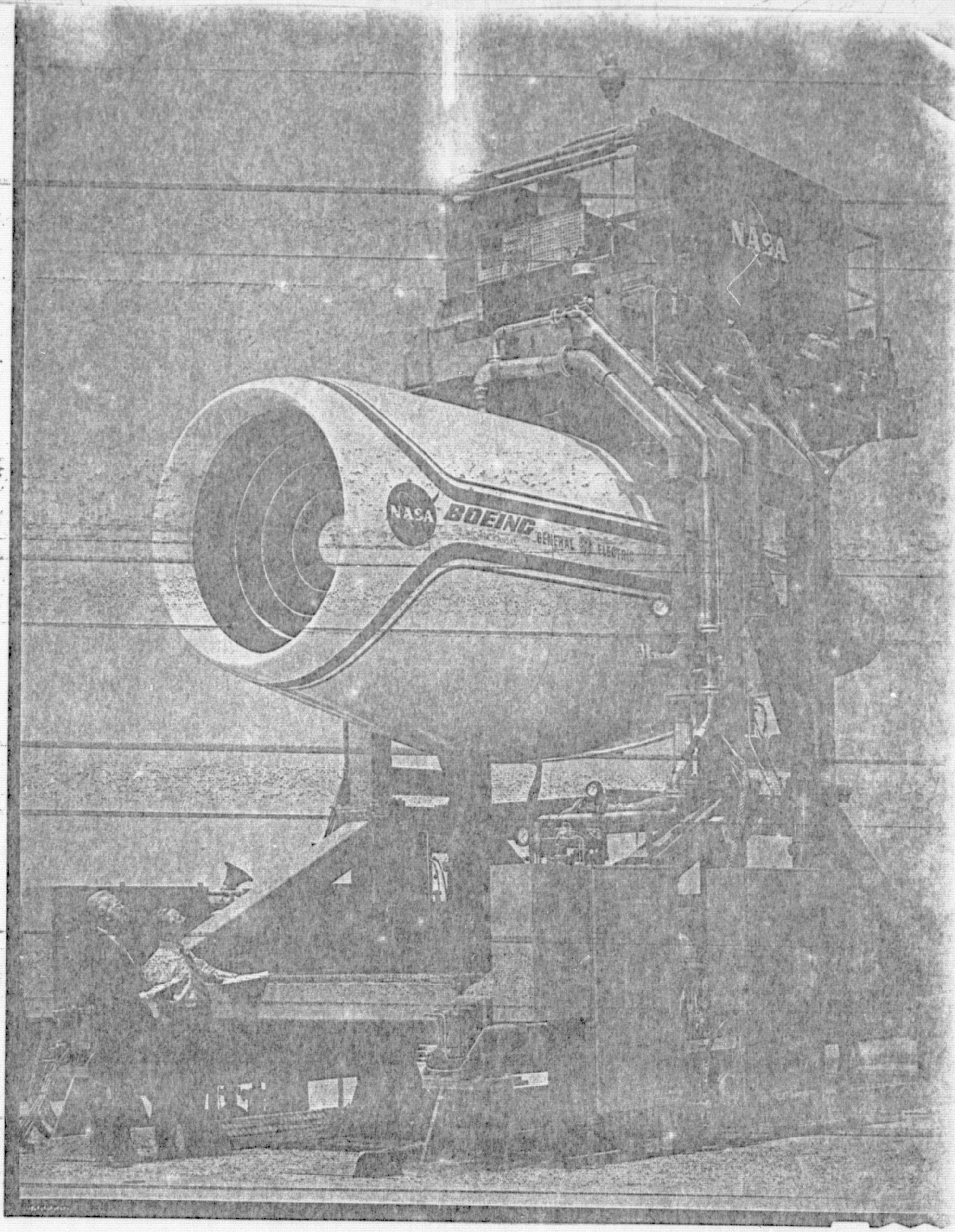
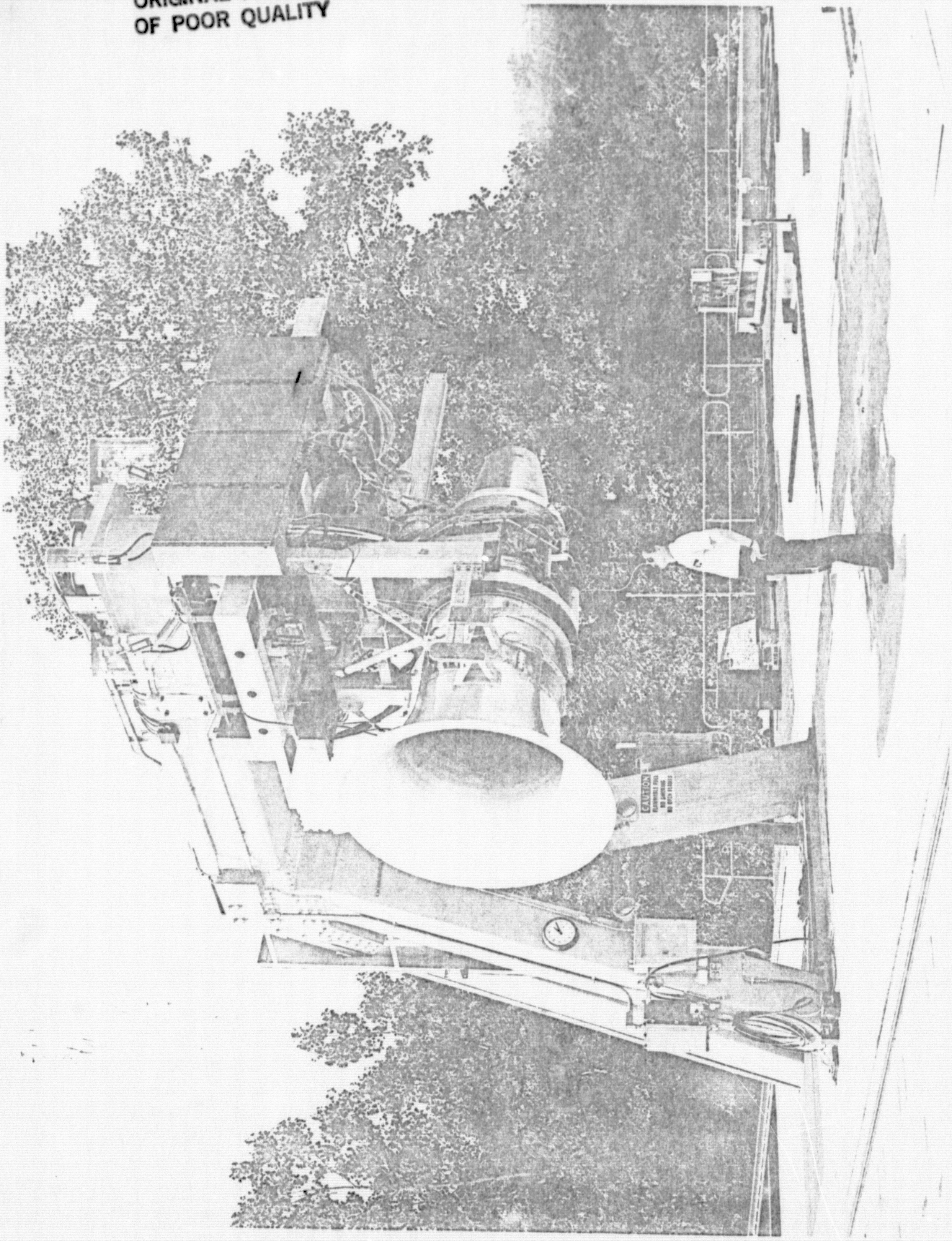

V/STOL AND NOISE DIVISION
PROPULSION SYSTEMS ACOUSTICS BRANCH
TURBOMACHINERY NOISE SECTION
ACOUSTICS SECTION
ENGINE NOISE SECTION
(19 PROFESSIONALS)
JET ACOUSTICS BRANCH
SECTION A
SECTION B
(12 PROFESSIONALS)
OPERATIONS BRANCH
SECTION A
SECTION B
(11 PROFESSIONALS)


NASA
NASA
BOEING
GENERAL ELECTRIC



C-75-2669

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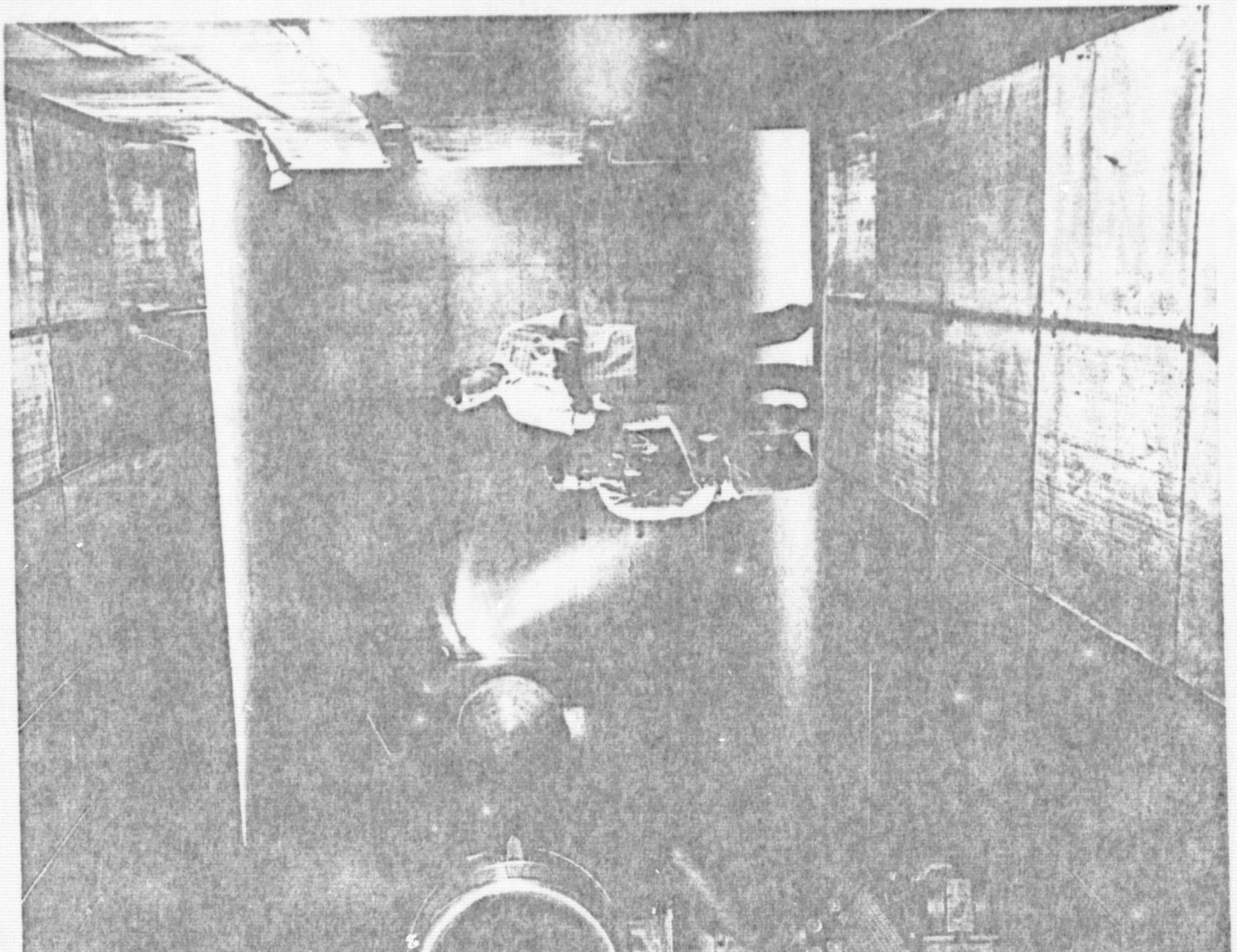
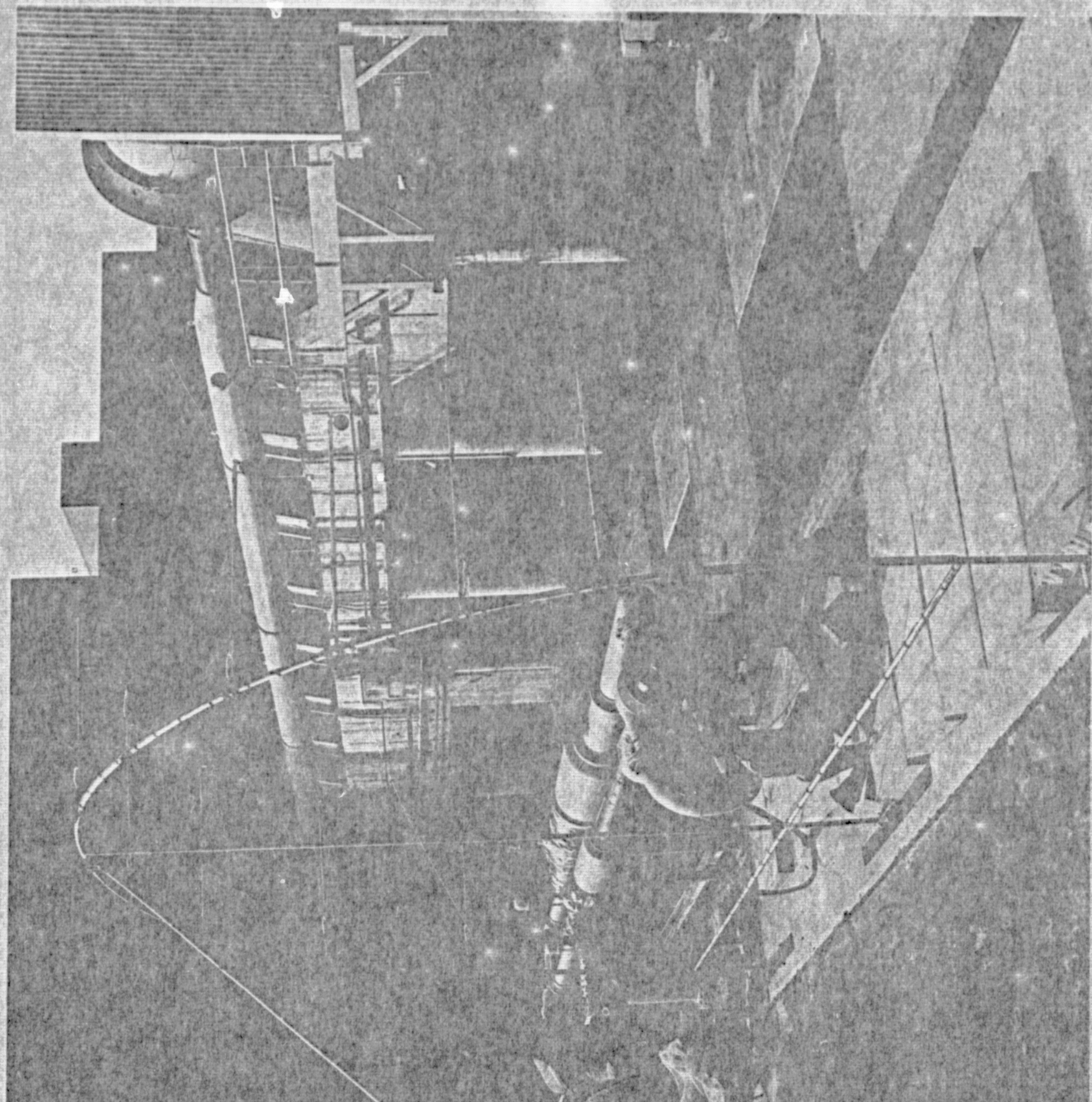
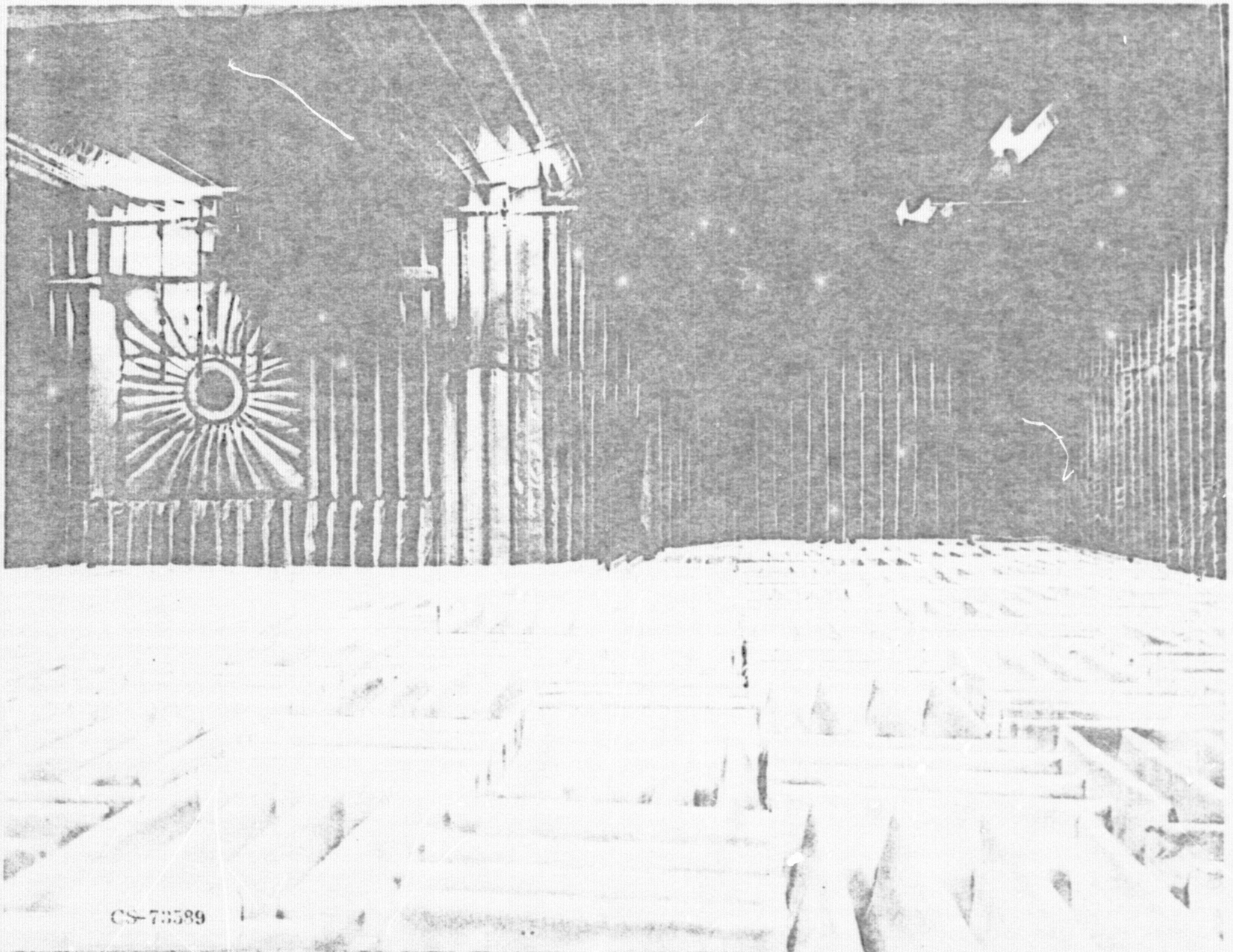


C-76-2750



ENGINE FAN & JET NOISE FACILITY



PROGRAM: PROPULSION ENVIRONMENTAL IMPACT MINIMIZATION R&T

SPECIFIC OBJECTIVE: PROPULSION NOISE RESEARCH

DESCRIPTION: RESEARCH EFFORTS ARE DIRECTED TOWARD UNDERSTANDING THE BASIC PRINCIPLES AND PHENOMENA INVOLVED IN THE GENERATION, PROPAGATION AND SUPPRESSION OF AIRCRAFT PROPULSION GENERATED NOISE. ALSO INCLUDED ARE STUDIES OF AERODYNAMIC FLOW INTERACTION WITH SURFACES, ATMOSPHERIC REFRACTION AND SCATTERING, AND THE DEVELOPMENT OF AN AIRCRAFT NOISE PREDICTION TECHNIQUE.

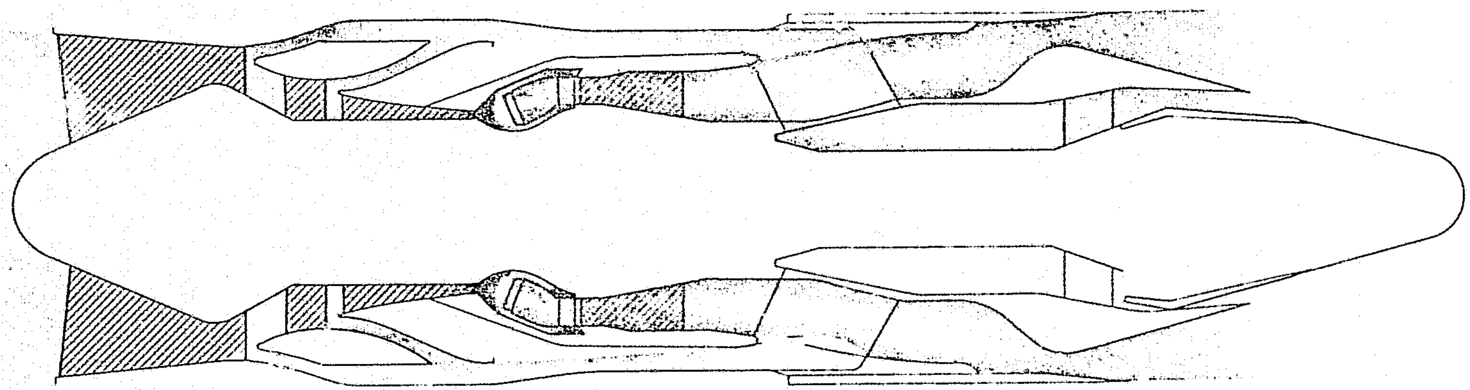
TARGETS:

- JET SOURCE NOISE AND PRACTICAL SOURCE NOISE REDUCTION CONCEPTS
- CORE SOURCE NOISE AND PRACTICAL SOURCE NOISE REDUCTION CONCEPTS
- DETERMINE THE EFFECTS OF FORWARD VELOCITY ON ENGINE GENERATED NOISE AND PROPAGATION
- JET/SURFACE INTERACTION SOURCE NOISE PRINCIPLES AND PRACTICAL MEANS FOR REDUCING SUCH NOISE
- FAN SOURCE NOISE AND SOURCE NOISE REDUCTION CONCEPTS (TURBOMACHINERY)
- ACOUSTIC SUPPRESSOR PRINCIPLES AND CONCEPTS

NASA
C-76-3865

DOUBLE BYPASS VCE

TAKEOFF/SUBSONIC CRUISE MODE

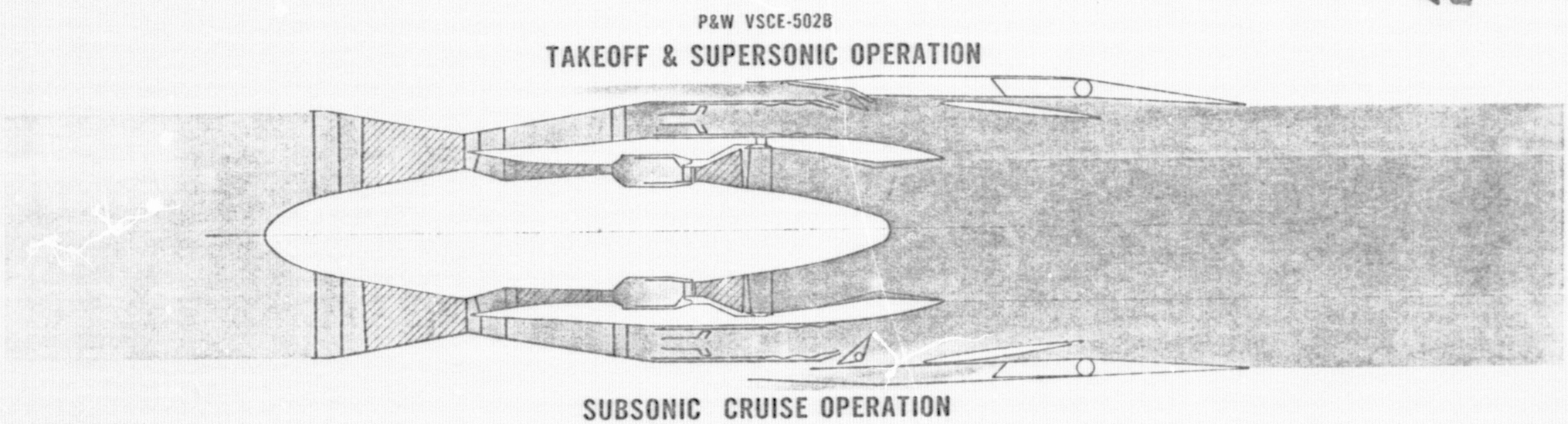


SUPERSONIC CRUISE MODE

CD-12044-02
C-76-3865

NASA
C-76-720

VARIABLE STREAM CONTROL ENGINE



CD - 11970 - 07

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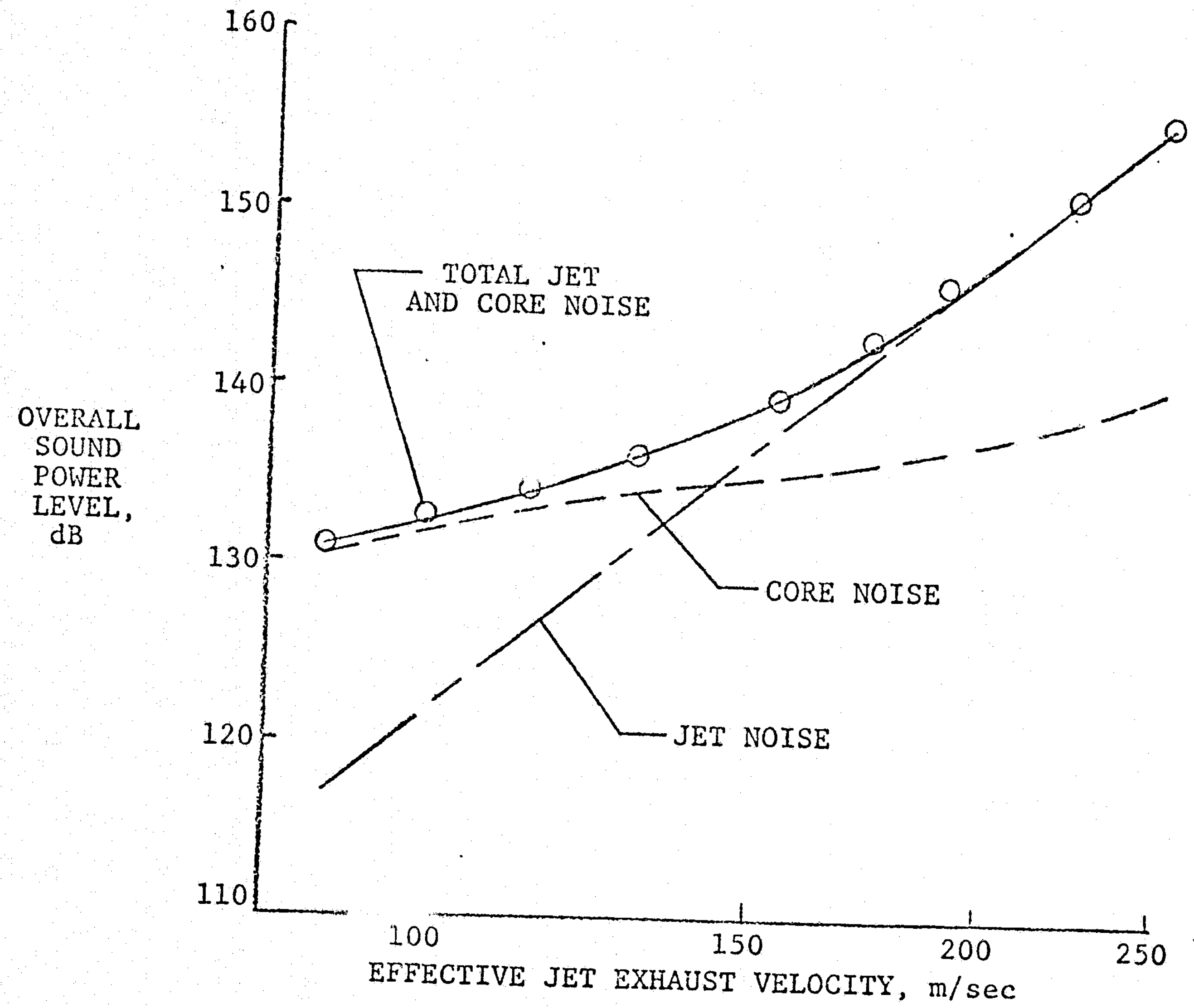
YF-102 ACOUSTIC POWER



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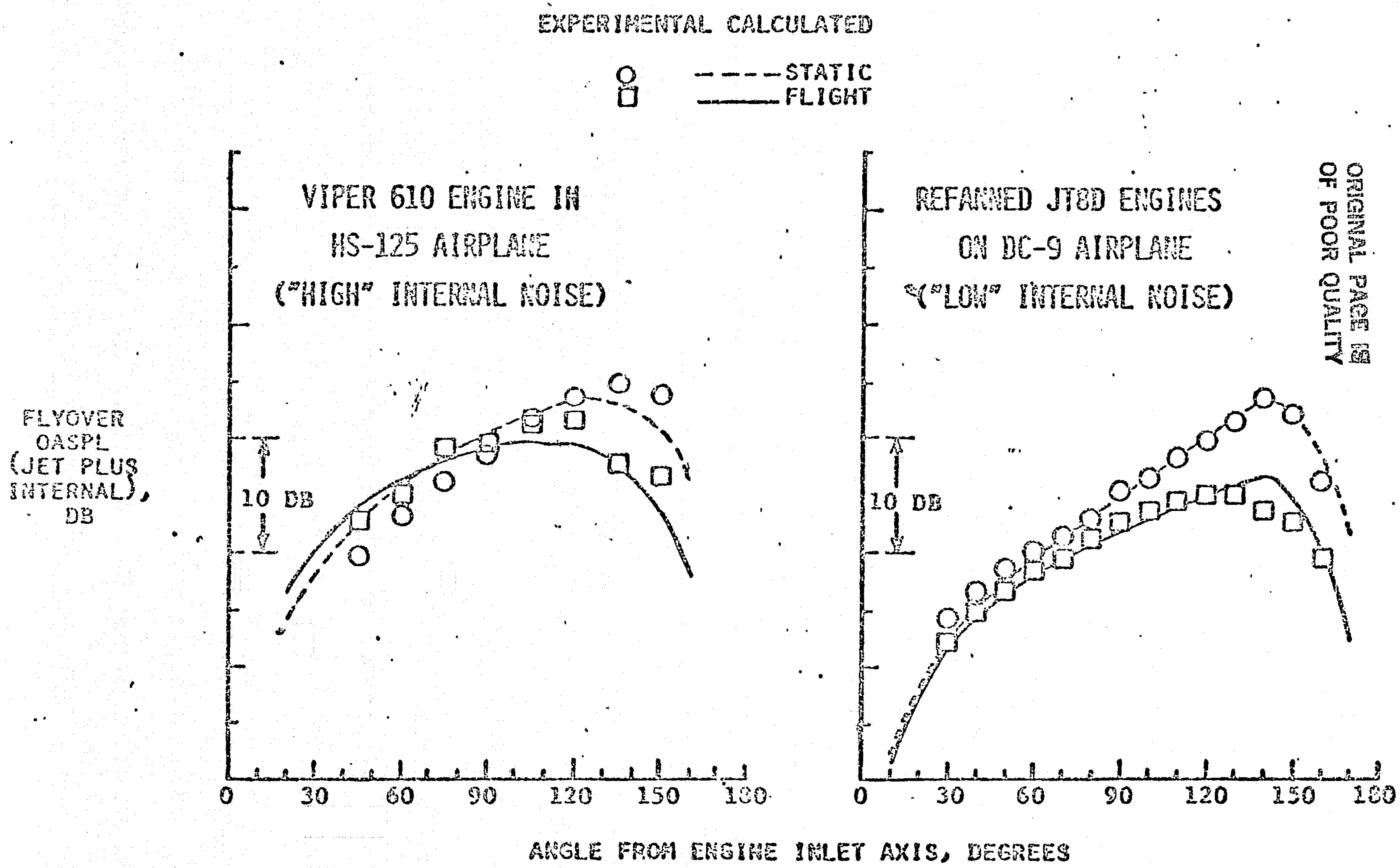
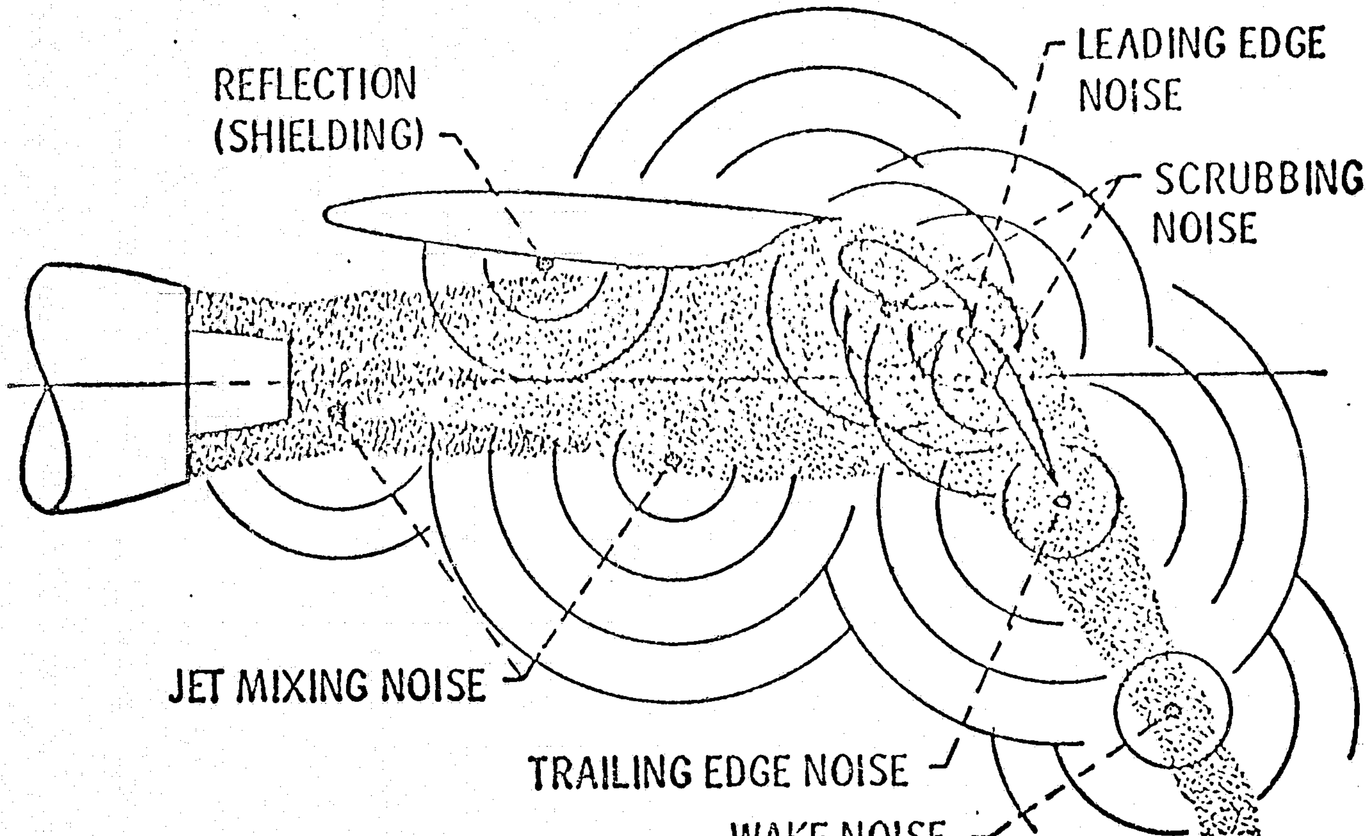
STATIC AND FLIGHT DIRECTIVITIES FOR ENGINES WITH DIFFERENT LEVELS OF INTERNAL NOISE RELATIVE TO JET NOISE

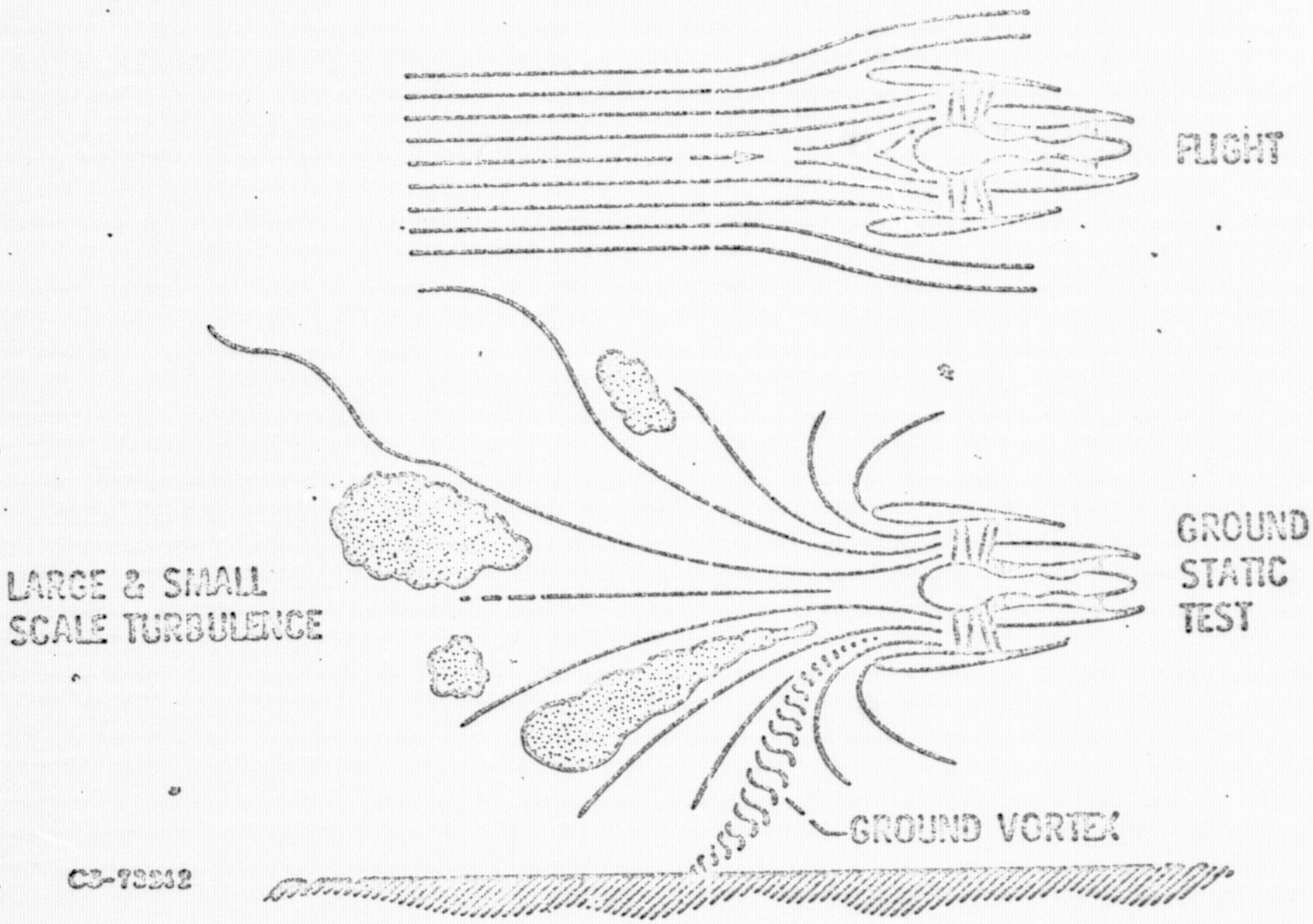


7

EXTERNALLY BLOWN FLAP NOISE SOURCES

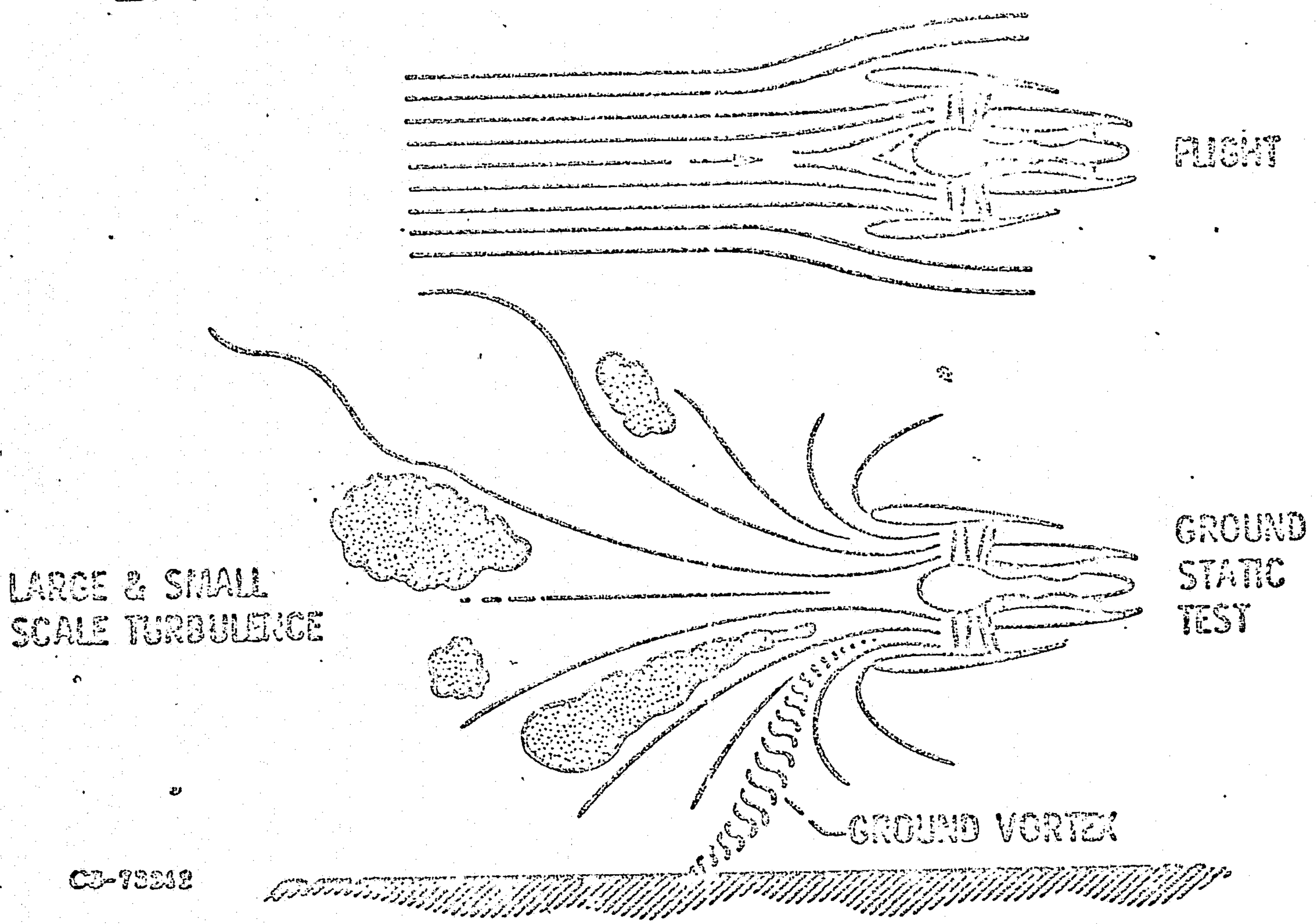


EFFECT OF FLIGHT ON INLET FLOW



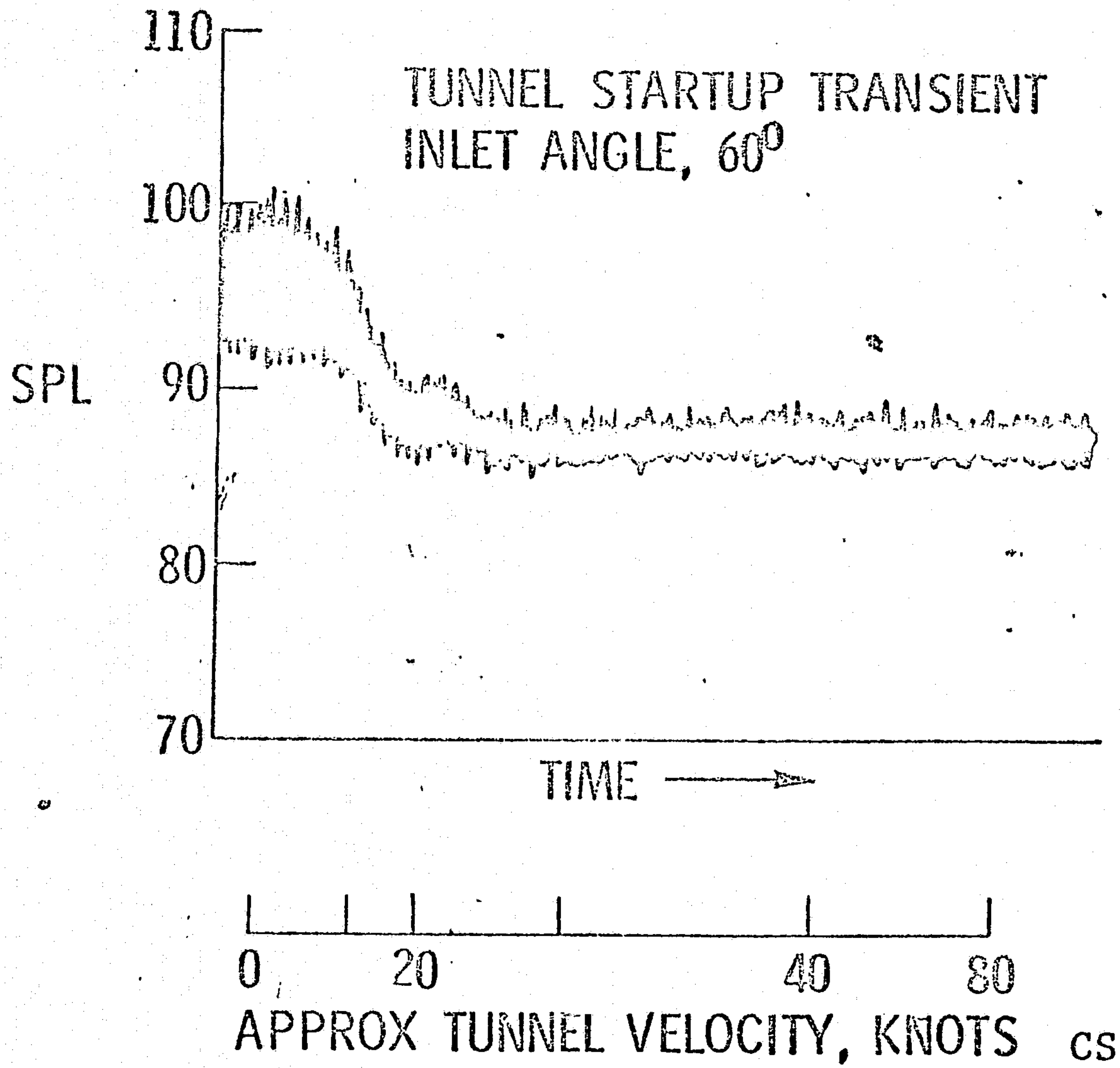
CS-78832

EFFECT OF FLIGHT ON INLET FLOW



CS-78812

BPF TONE CUT-OFF AND UNSTEADINESS



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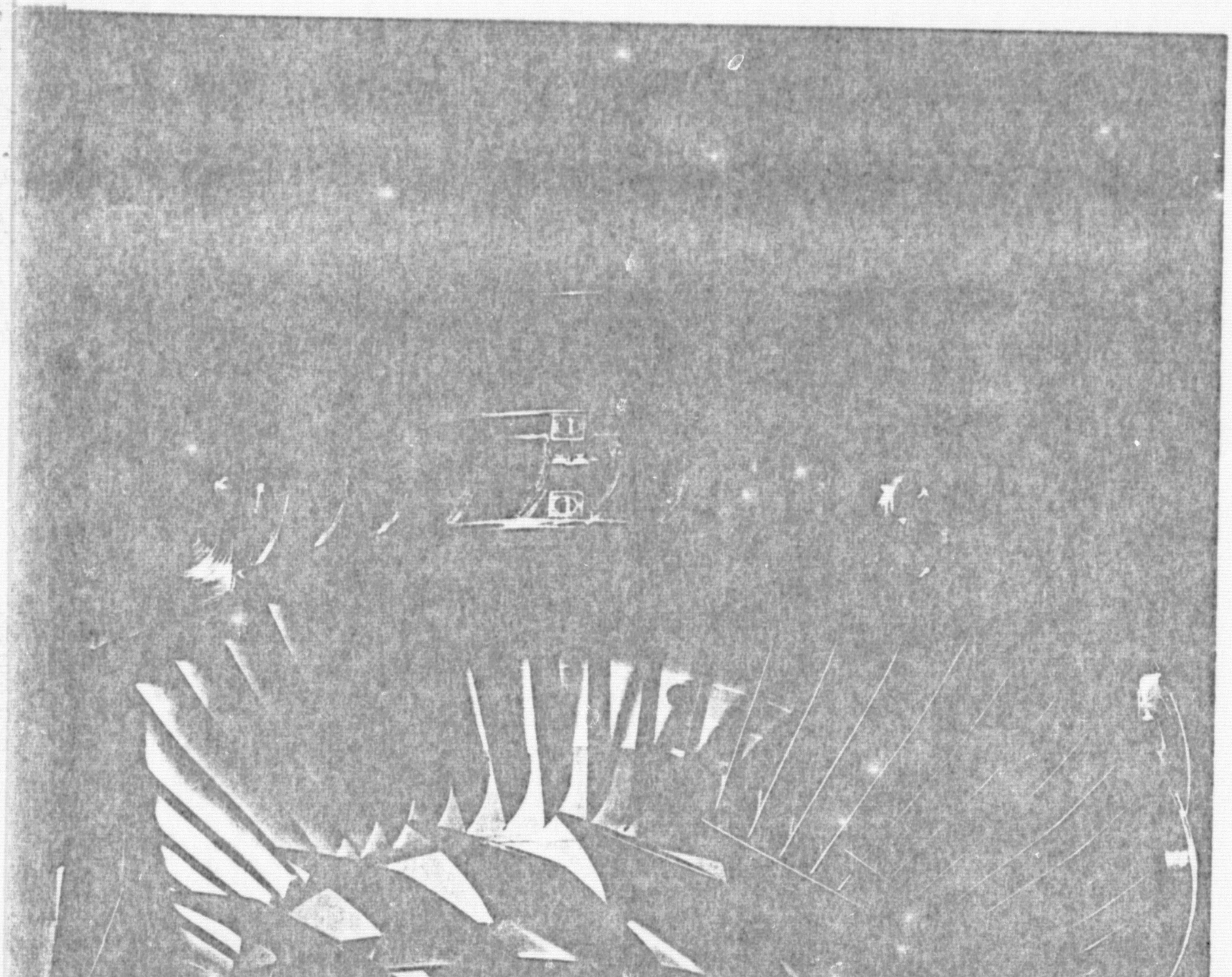
CS-78704



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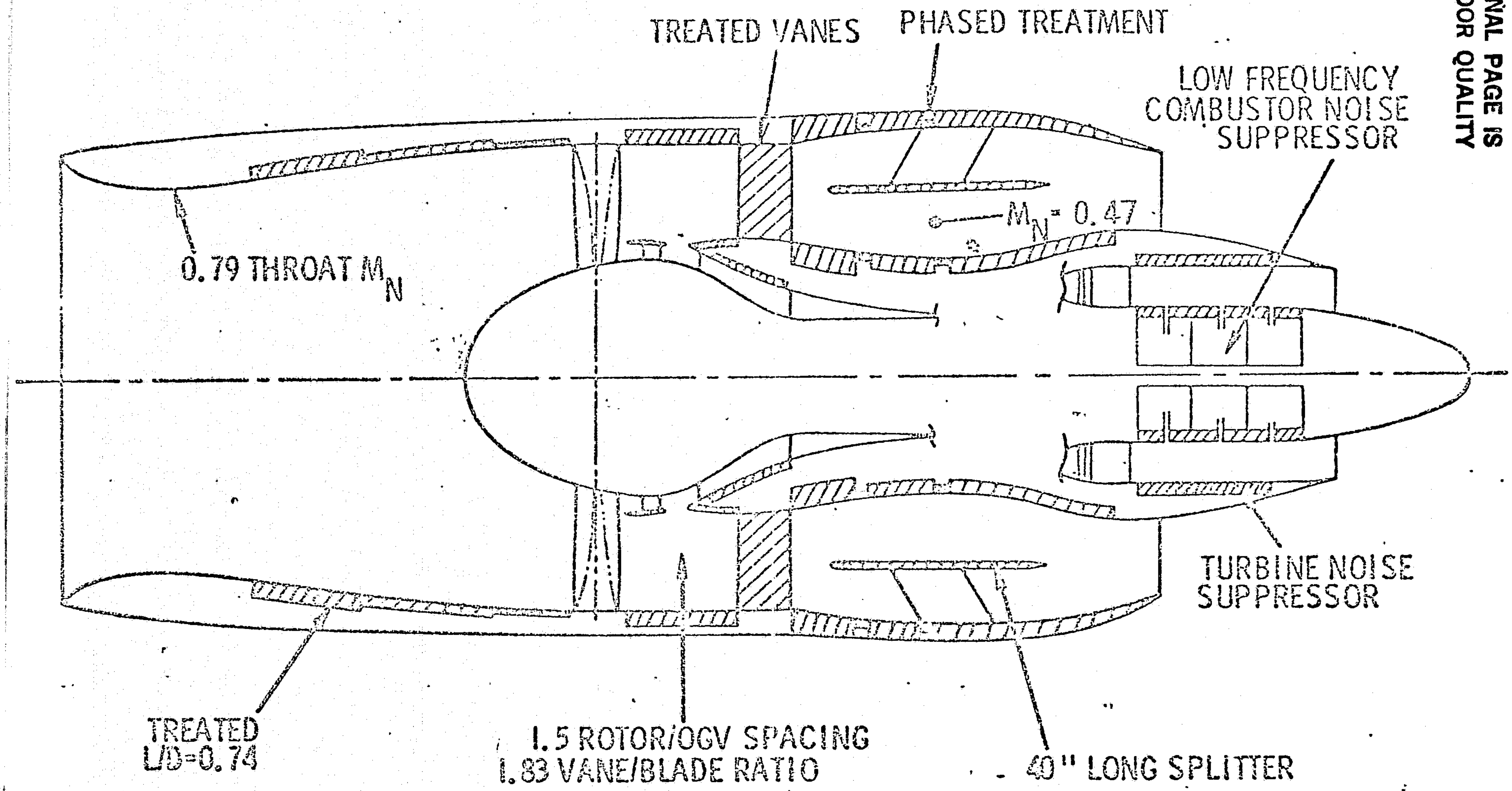
QCSEE UTW ENGINE

o p/p = 1.26 o TIP SPEED = 930 ft/sec o BLADE NO.=18



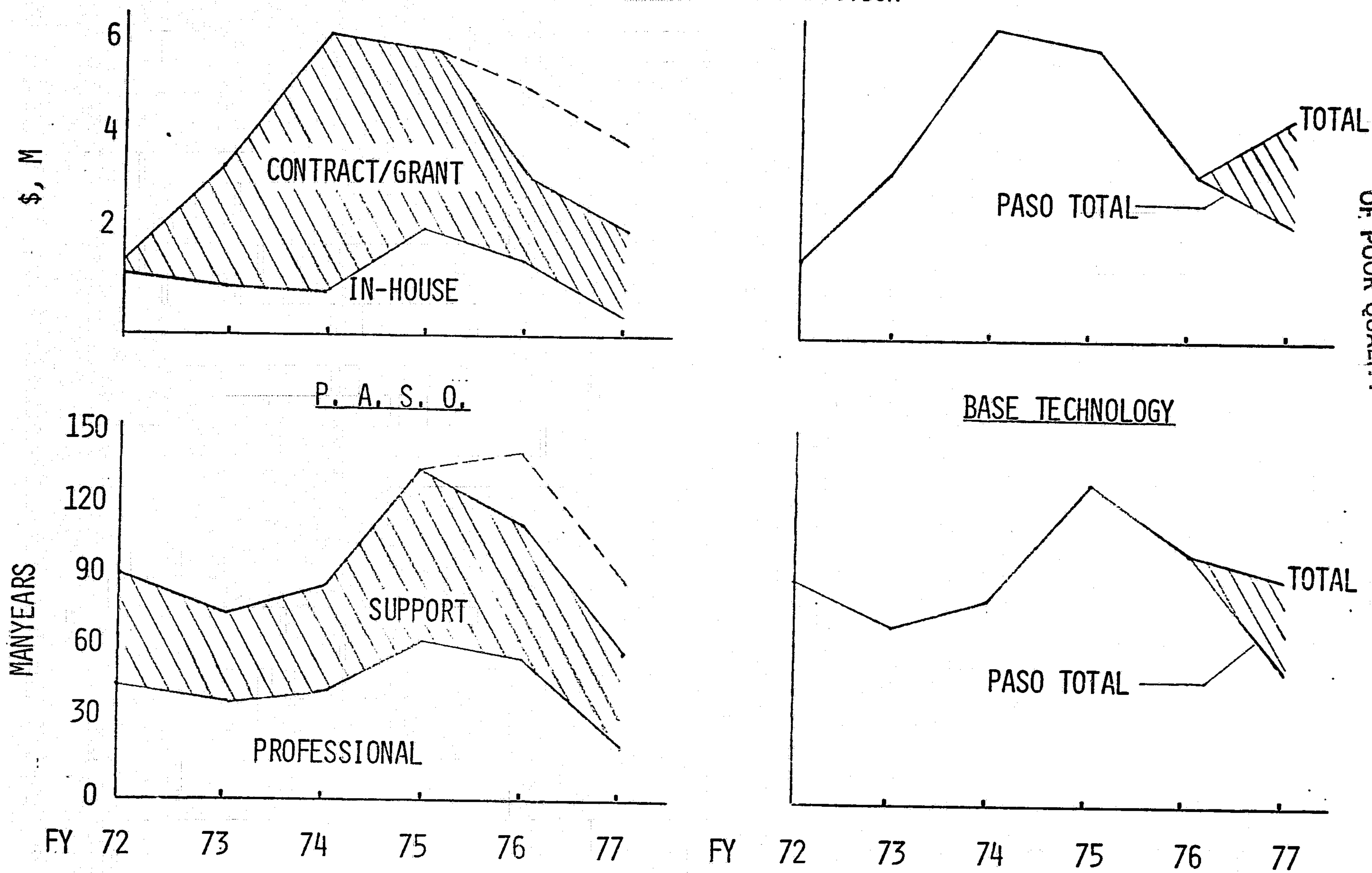
PROPULSION ENVIRONMENTAL IMPACT MINIMIZATION

PROPULSION POLLUTION REDUCTION RESEARCH

DONALD A. PETRASH - AIRBREATHING ENGINES DIVISION

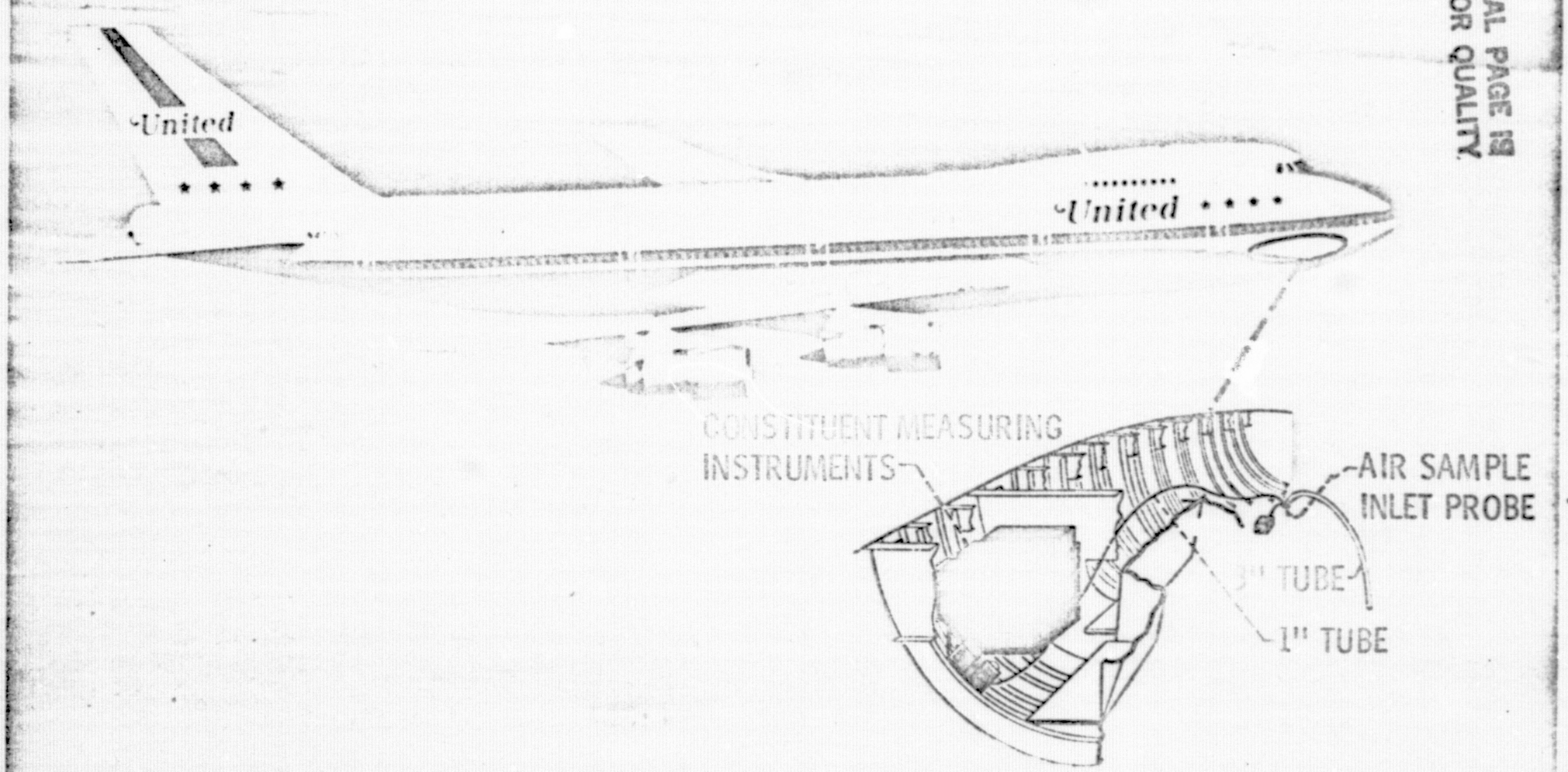
R & T TRENDS

PROPULSION POLLUTION REDUCTION



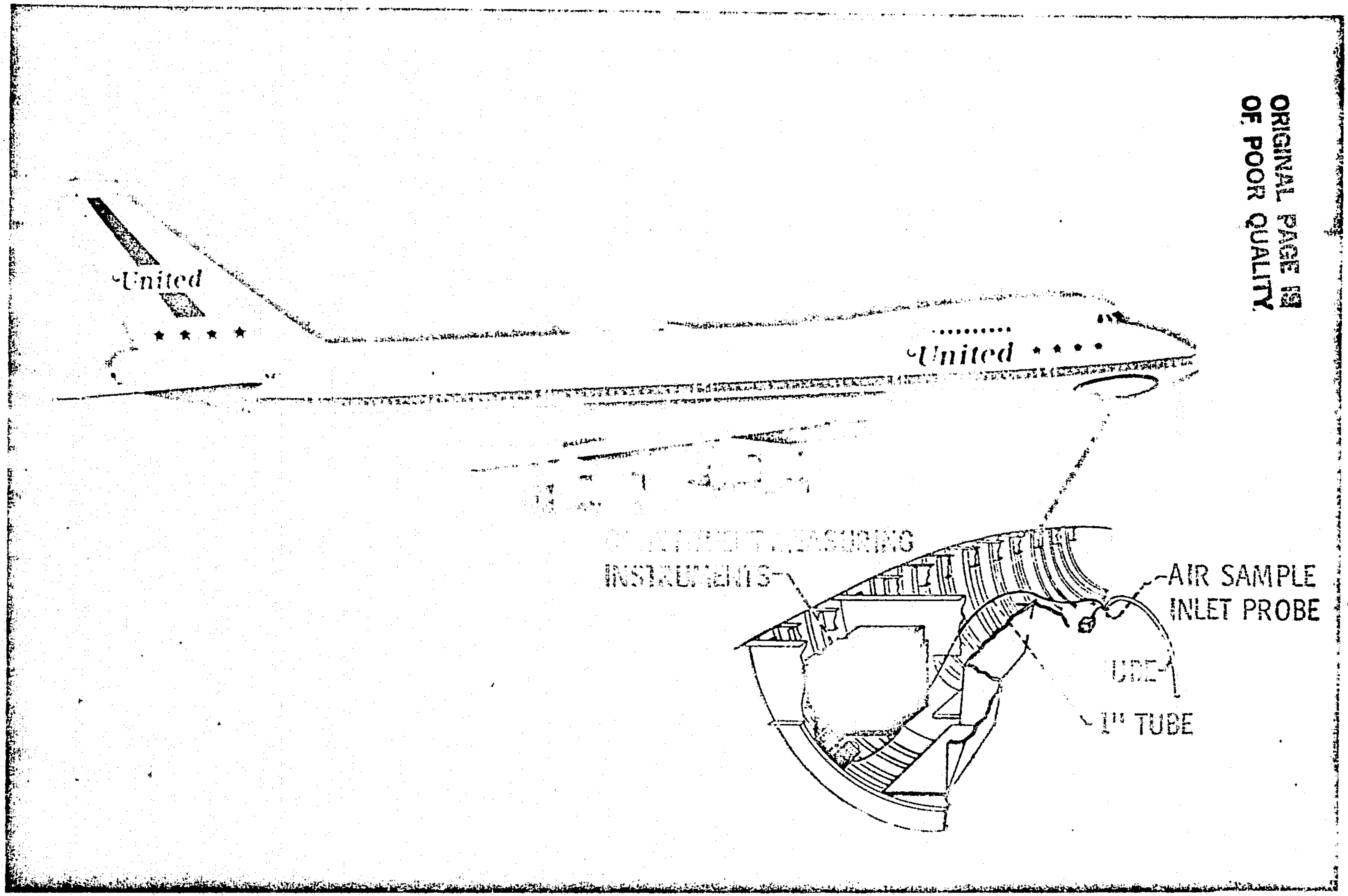
NASA
C-74-1212

GLOBAL ATMOSPHERIC SAMPLING PROGRAM

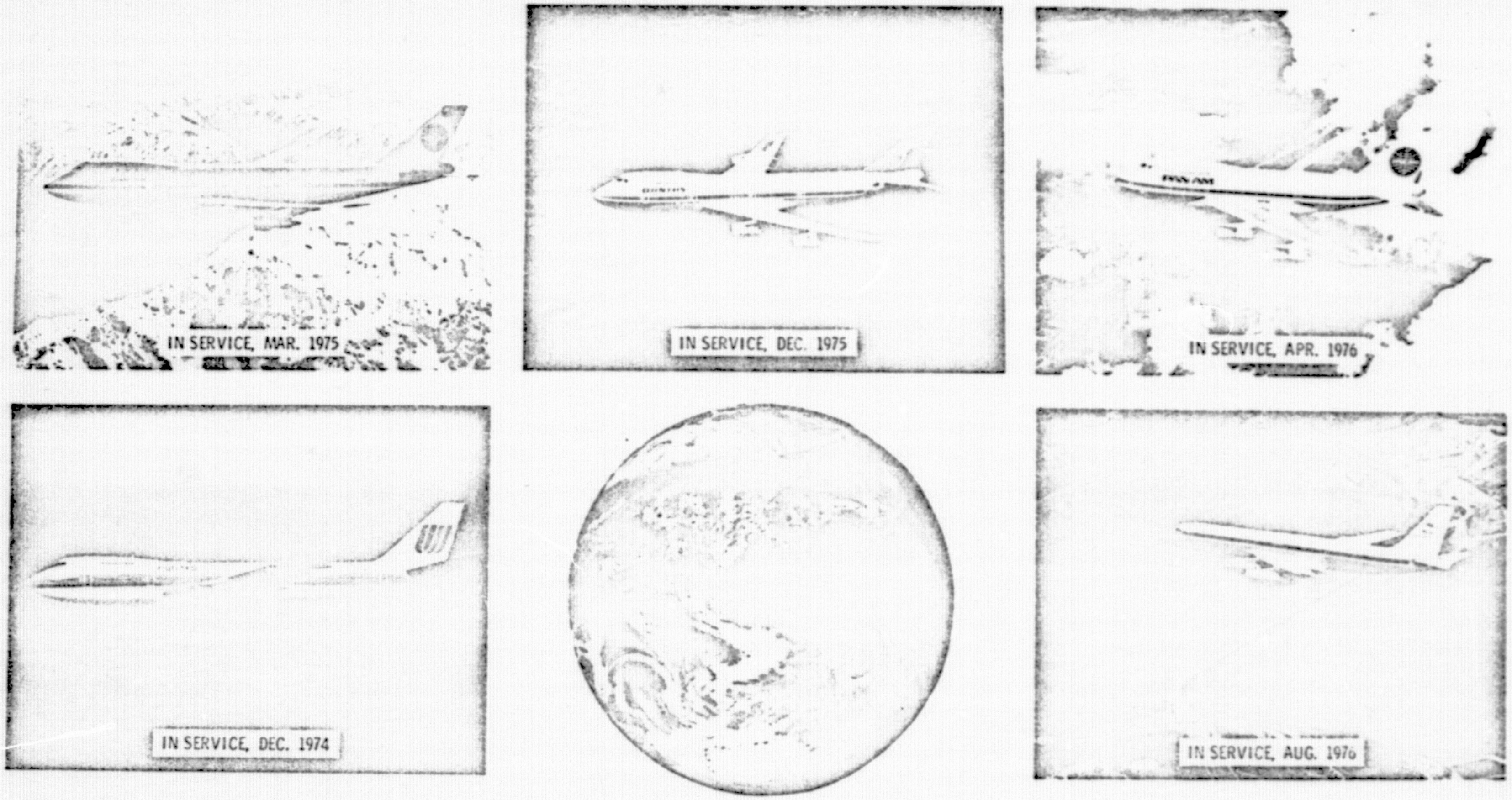


NASA
C-74-1212

GLOBAL ATMOSPHERIC SAMPLING PROGRAM



C-76-4842



GASP MEASUREMENTS

PARTICULATES	FILTER SAMPLES	GASES	RELATED INFORMATION
NUMBER DENSITY	SULFATES	OZONE	GEOGRAPHICAL LOCATION
SIZE DISTRIBUTION	NITRATES	WATER VAPOR	METEOROLOGICAL CONDITIONS
	CHLORIDES	OXIDES OF NITROGEN	AIRCRAFT OPERATING CONDITIONS
		CARBON MONOXIDE	
		CHLOROFLUOROMETHANES	

COMBUSTION & POLLUTION RESEARCH BRANCH
DON A. PETRASH

- **ENVIRONMENTAL IMPACT SECTION**
  E. A. LEZBERG

- **EXPERIMENTAL COMBUSTOR SECTION**
  ROBERT E. JONES

  RICHARD W. NIEDZWIECKI

- **EMISSIONS TECHNOLOGY SECTION**
  LARRY A. DIEHL

  LARRY P. COOPER
  ROBERT A. DUERR
  VALERIE J. LYONS
  CECIL J. MAREK
  EDWARD J. MULARZ
  GREGORY M. RECK
  ANDREW J. SZANISZLO

- **ADVANCED TECHNOLOGY SECTION**
  JACK B. GROBMAN

  HELMUT F. BUTZE
  JAMES S. FEAR
  CARL T. NORGREN

GENERAL AVIATION BRANCH
E. A. WILLIS

- **SPARK IGNITION SECTION**
  ERWIN E. KEMPKE

  JOHN CASSIDY
  DONALD COSGROVE
  PEGGY EVANICH
  MICHAEL SKOROBATCKYI

RESEARCH FACILITIES

GAS TURBINE COMBUSTORS -

FACILITY	MAX. AIRFLOW LB/SEC	MAX. PRES. PSIA	MAX. INLET TEMP,. °F
CELL 11, ORL	5-10	120	500-1000
*CE5A, ERB	35	450	700-1200
ECRL-1	110	120	1150

C-2

SPARK IGNITION ENGINES -

FACILITY	ENGINE TYPE	INTAKE AIR	DYNAMOMETER HP/RPM
SE-17	A/C	TEMP. HUMIDITY CONTROLLED	300/500
SE-11	MULTI-CYLINDER	AMBIENT	250/4500
SE-12	SINGLE-CYLINDER	AMBIENT	50/5000

*OPERATIONAL IN 1978

PREMIXED PRIMARY ZONE TEST SECTION

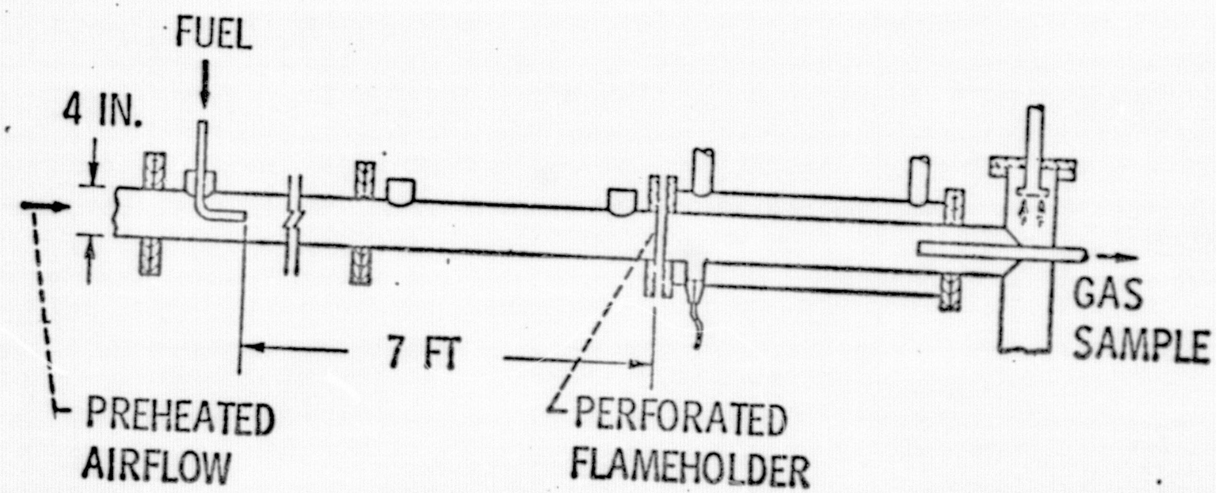


PHOTO OF SE 17 (Non-Reproducible)

SPECIFIC OBJECTIVE: PROPULSION POLLUTION REDUCTION RESEARCH

VARIOUS TECHNIQUES FOR REDUCING POLLUTANT EMISSIONS FROM AIRCRAFT POWER PLANTS FOR LANDING TAKEOFF-CYCLE (LTD) ARE BEING EXPLORED. GAS TURBINE COMBUSTOR DESIGN CONCEPTS ARE BEING EVALUATED AND NUMEROUS ANALYTICAL AND EXPERIMENTAL STUDIES ARE BEING PERFORMED TO IDENTIFY PLAUSIBLE APPROACHES.

TARGETS:

- EVALUATE THE POTENTIAL OF ADVANCED TECHNOLOGY ENGINE COMBUSTORS TO REDUCE EXHAUST EMISSIONS POLLUTION TO 10 PERCENT OF CURRENT LEVELS FOR CO AND THC AND 25 PERCENT FOR NO_X, AND DEMONSTRATE THESE REDUCTIONS IN HIGH PRESSURE, HIGH TEMPERATURE TEST FACILITIES - FY 1981

- DETERMINE THE POTENTIAL OF ADVANCED EMISSION REDUCTION CONCEPTS FY 1980

TARGET: EVALUATE AND DEMONSTRATE THE POTENTIAL OF ADVANCED TECHNOLOGY ENGINE COMBUSTORS TO REDUCE EXHAUST EMISSION POLLUTION

PRINCIPAL PROGRAM ELEMENTS:

IN-HOUSE

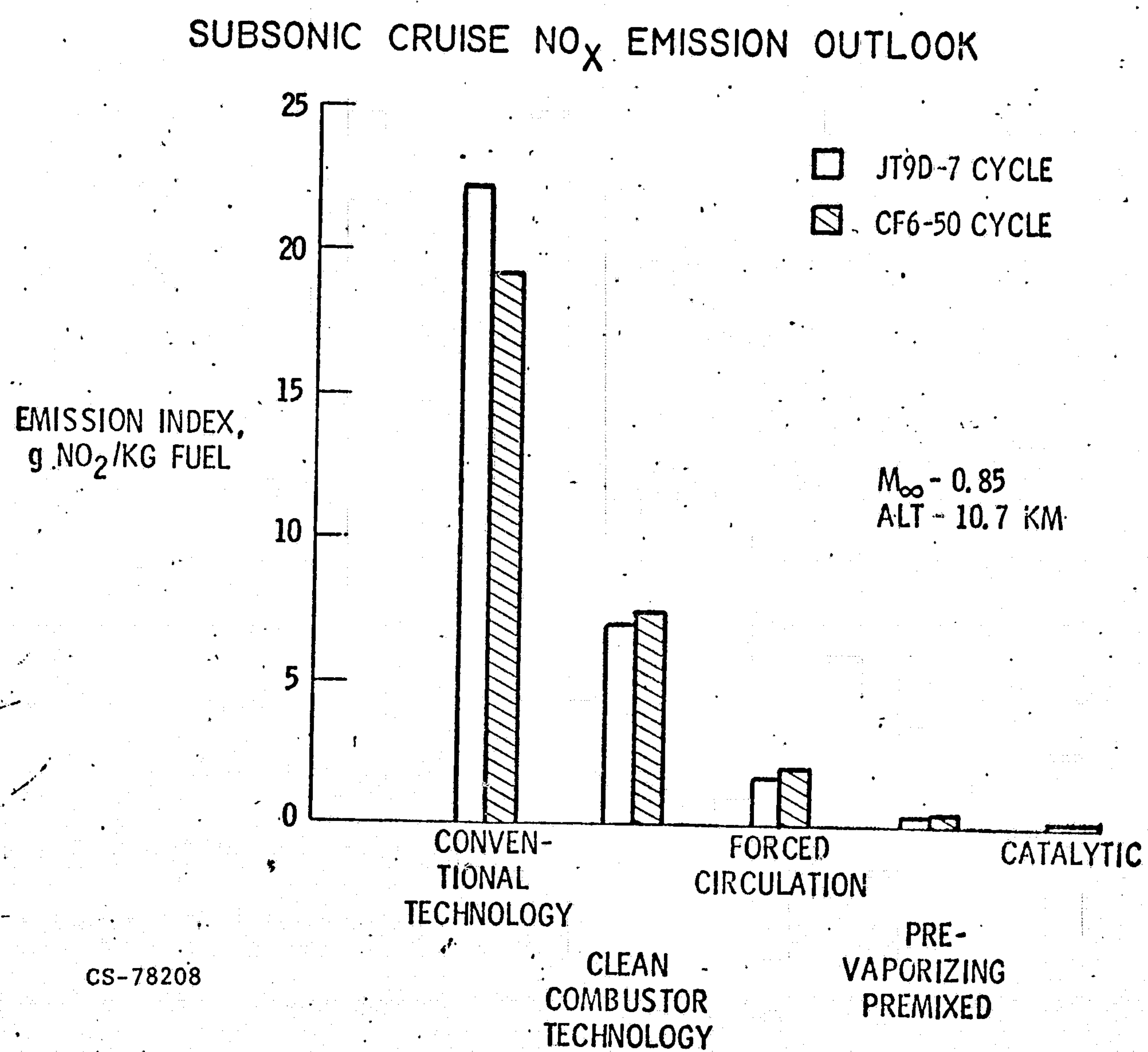
- FLAMEHOLDER GEOMETRY EFFECTS ON EMISSIONS
- EFFECT OF DROP SIZE ON EMISSIONS
- FUEL PREPARATION STUDY
- EFFECT OF HOT SURFACES/BOUNDARY LAYERS IN PREMIXING PASSAGES
- CONCEPTUAL DESIGN STUDY (SECTOR TESTS)

CONTRACT/GRANT

- AUTOIGNITION STUDY (UTRC)
- PRESSURE AND TEMPERATURE EFFECTS ON EMISSIONS (GASL)
- FLAMEHOLDER GEOMETRY STUDY (GASL)
- COMPRESSOR DISCHARGE CHARACTERIZATION (G.E.) (P&WA)
- FUEL PREPARATION MODEL
- FUEL PREPARATION DATA
- LEAN STABILITY AUGMENTATION STUDY
- EXPERIMENTAL CLEAN COMBUSTOR PHASE III
  - GENERAL ELECTRIC CF6-50
  - PRATT & WHITNEY JT9D-7

CONTRACT/GRANT (CONT.)

- POLLUTION REDUCTION TECHNOLOGY PHASE II
  - GARRETT/AIRESEARCH
- LOW POWER EMISSIONS REDUCTION (G.E.)
- LOW NO_X COMBUSTORS (SOLAR)
- VSCE DUCT BURNER (P&WA)
- LOW EMISSIONS DUCT BURNER (G.E.)
- FLOW PROCESSES IN COMBUSTORS - CORNELL UNIVERSITY
- LEAN COMBUSTION TECHNOLOGY - UNIV. OF CALIFORNIA AT BERKELEY
- COMBUSTION AERODYNAMICS AND POLLUTANT FORMATION - MIT
- SOOT FORMATION AND BURNOUT IN FLAMES - MIT


SUBSONIC CRUISE NO_X EMISSION OUTLOOK
25
20
15
10
5
0
EMISSION INDEX, g NO_2/KG FUEL
JT9D-7 CYCLE
CF6-50 CYCLE
M_∞ - 0.85
ALT - 10.7 KM
CONVEN-TIONAL TECHNOLOGY
CLEAN COMBUSTOR TECHNOLOGY
FORCED CIRCULATION
PRE-VAPORIZING PREMIXED
CATALYTIC

CS-78208

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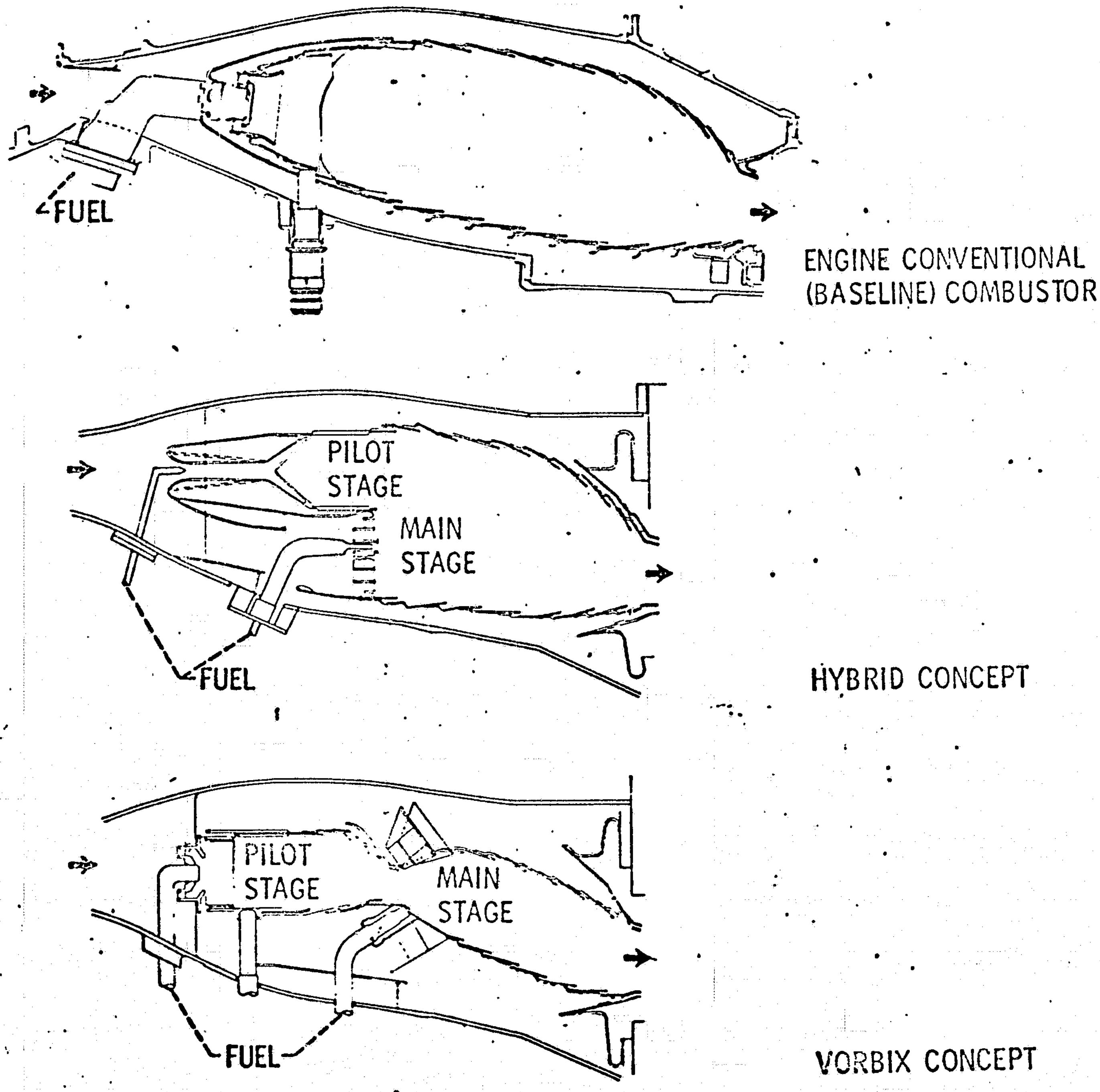
EXPERIMENTAL CLEAN COMBUSTOR PROGRAM

T2 CLASS, JT9D-7 ENGINE



TARGET: DETERMINE THE POTENTIAL OF ADVANCED EMISSION REDUCTION CONCEPTS - FY '80

PROGRAM:

IN-HOUSE

- TEMPERATURE/HUMIDITY CORRELATION FOR AIRCRAFT ENGINE EMISSIONS
- FUEL INJECTION, HIGH ENERGY SPARK, LEAN OPERATION

CONTRACT

- FAA/NASA INTERAGENCY PROGRAM
- TELEDYNE CONTINENTAL MOTORS EXHAUST EMISSION REDUCTION
- AVCO-LYCOMING EXHAUST EMISSION REDUCTION

PROPULSION POLLUTION REDUCTION RESEARCH

MAJOR CONTRIBUTIONS '72-'77

- DEMONSTRATION OF EMISSIONS REDUCTION WITH A DOUBLE ANNULAR COMBUSTOR AND WITH A VORBIX TWO-STAGE COMBUSTOR IN THE EXPERIMENTAL CLEAN COMBUSTOR PROGRAM.
- DEVELOPMENT AND DEMONSTRATION OF POLLUTION REDUCTION COMBUSTOR TECHNOLOGY IN T1, P2, AND T4 CLASSES OF ENGINES.
- DEMONSTRATION OF LOW-NO_X CAPABILITY OF SWIRL-CAN COMBUSTORS IN ECRL.
- DEMONSTRATION OF NO_X EMISSION INDEX <1 USING A PREMIXED-PREVAPORIZED COMBUSTOR AND ALSO A CATALYTIC COMBUSTOR.
- DEMONSTRATION OF EXHAUST GAS RECIRCULATION FOR FLAME STABILIZATION AND NO_X REDUCTION.
- DEMONSTRATION OF H_2O INJECTION FOR NO_X CONTROL.
- DETERMINATION OF THE EFFECT OF INLET-AIR HUMIDITY ON NO_X FORMATION.
- EXPERIMENTALLY CHARACTERIZED EMISSIONS FROM TEN DIFFERENT PISTON ENGINE TYPES. ALSO HAVE ESTABLISHED EFFORTS OF VARYING FUEL-AIR RATIO AND IGNITION TIMING ON EMISSION LEVELS.
- COMPLETED TESTING ON TWO AIRCRAFT PISTON ENGINES TO DETERMINE EFFECTS ON EMISSIONS OF TEMPERATURE AND HUMIDITY.

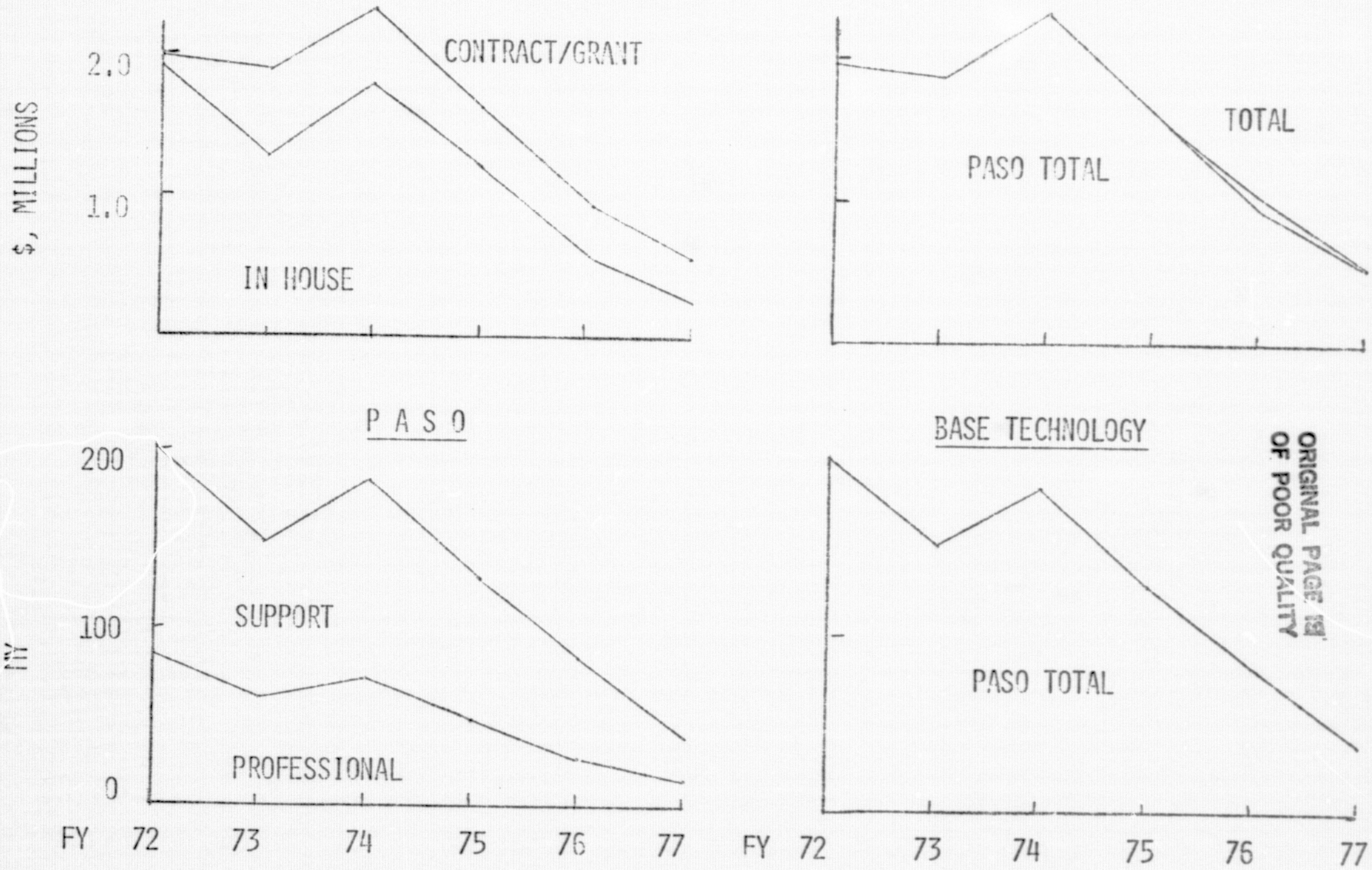
ECCP /JT9D-7 POLLUTANT LEVELS

	CO	THC	NO_X
GOAL	4.3	0.8	3.0
PRODUCTION COMBUSTOR	8.5	3.9	5.9
VORBIX COMBUSTOR	3.3	0.3	2.6

DISCIPLINE/SUB-PROG.	PROPULSION COMPONENTS
SPECIFIC OBJECTIVE	INLET AND NOZZLE RESEARCH
PRESENTER	DAVID N. BOWDITCH CHIEF, PROPULSION AERODYNAMICS BRANCH WIND TUNNEL AND FLIGHT DIVISION

R&T TRENDS

INLET AND NOZZLE RESEARCH



PROPULSION AERODYNAMICS BRANCH

DAVE BOWDITCH

SUPERSONIC PROPULSION SECTION	AERODYNAMIC ANALYSIS SECTION	SUBSONIC PROPULSION SECTION
BOB COLTRIN	BERNIE ANDERSON	DAN MIKKELSON
INLETS	COMPUTATIONAL FLUID DYNAMICS	PROPELLERS
DISTORTION	BENCHMARK EXPERIMENTS	NOZZLES

INLET PROGRAM
72 TO PRESENT

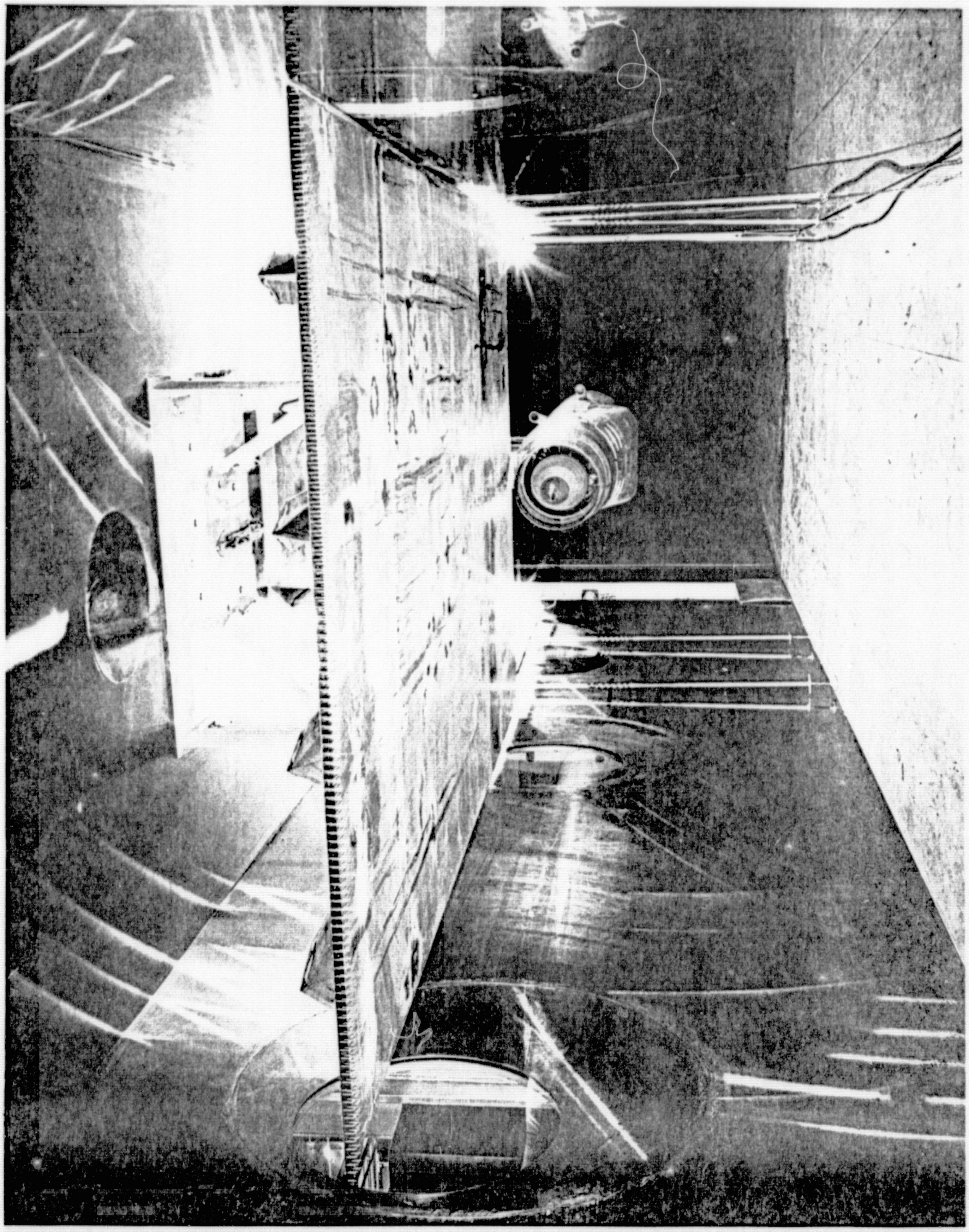
MATRIX OF 2D AND AXISYMMETRIC INLETS
- SUPERSONIC PERFORMANCE
- TRANSONIC PERFORMANCE

INLET ENGINE COMPATABILITY
- DISTORTION - STALL CORRELATION
- STABILITY
- UNSTART - RESTART
- STALL OVERPRESSURE

INLET AIRFRAME INTEGRATION

GENERATE ANALYTICAL METHODS

NASA
C-68-4156



INLET PROGRAM

GENERATE ANALYTICAL METHODS

CURRENT - ITERATION BETWEEN INVISCID AND BOUNDARY LAYER ANALYSIS

NEAR TERM - FULLY VISCOUS SUBSONIC 3D ANALYSIS
FULLY VISCOUS SUPERSONIC 2D ANALYSIS

FAR TERM - FULLY VISCOUS SUBSONIC, TRANSONIC, AND SUPERSONIC 3D ANALYSIS
PATCHED ANALYSIS FOR SEPARATED FLOWS

CONCEPTUAL INLET STUDIES

DISTORTION - STATISTICAL ANALYSIS
WT/FLT COMPARISON

BOUNDARY LAYER CONTROL - BLOWING, 2D INLET, SHORT DIFFUSERS

HIGH α, β INLET PERFORMANCE

FOCUSED APPLICATIONS

MILITARY - STEALTH, VTOL

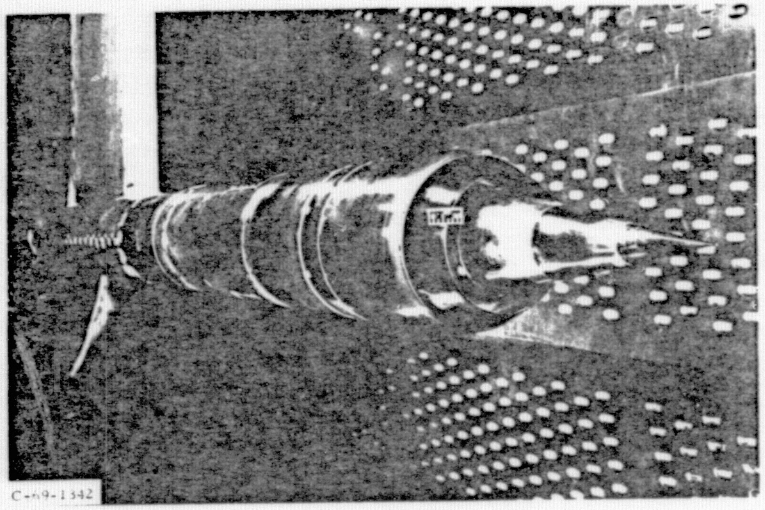
SCAR

NOZZLE PROGRAM

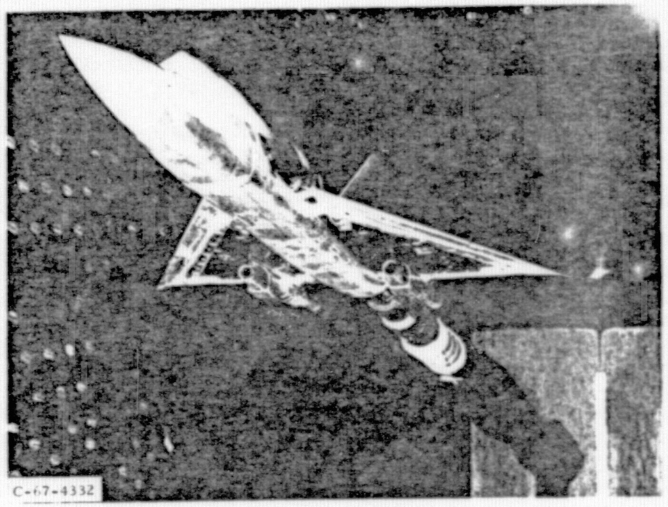
72 TO PRESENT

- SUPERSONIC CRUISE
  - INTERNAL PERFORMANCE
    - EXPERIMENT
    - ANALYSIS
  - INSTALLED TRANSONIC PERFORMANCE
    - WIND TUNNEL
    - FLIGHT
  - NOISE SUPPRESSOR
    - FLY-BY NOISE
    - FLY-BY PERFORMANCE
  - COOLING
- MILITARY
  - BOATTAIL DRAG VARIATION WITH REYNOLD'S NUMBER
    - WIND TUNNEL
    - FLIGHT
  - NON-AXISYMMETRIC NOZZLES
    - ANALYSIS
    - COOLING
- SUBSONIC CRUISE
  - MIXER ANALYSIS AND EXPERIMENTAL INVESTIGATION

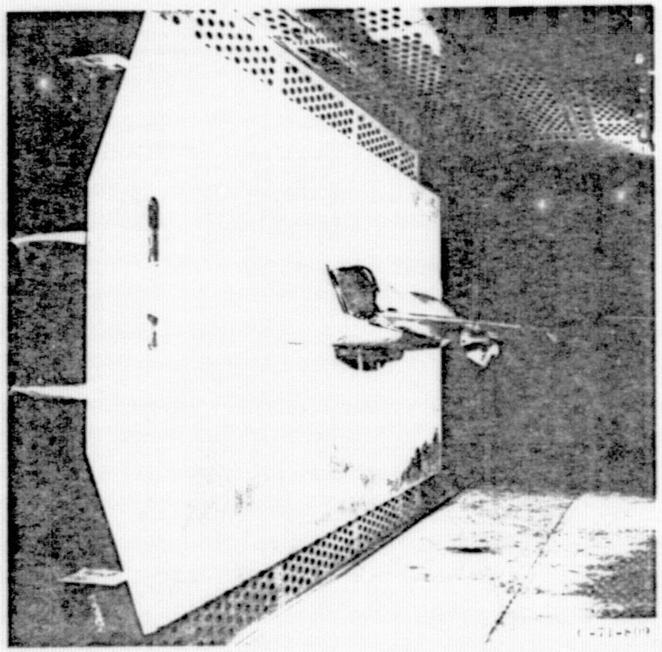
EXHAUST NOZZLE TEST PROGRAMS

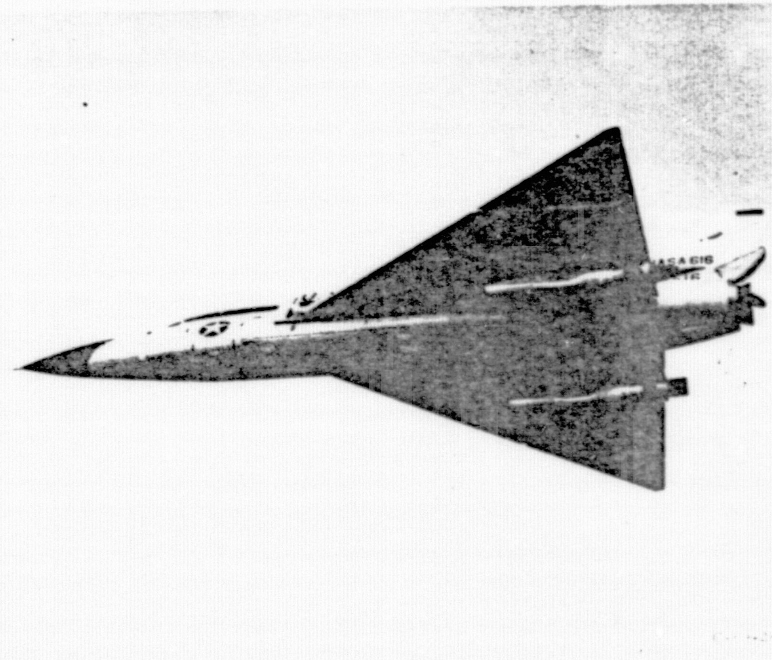


ISOLATED NOZZLE



5% SCALE F106


22 SCALE F106


F106 FLIGHT

PROGRAM: PROPULSION COMPONENTS R&T

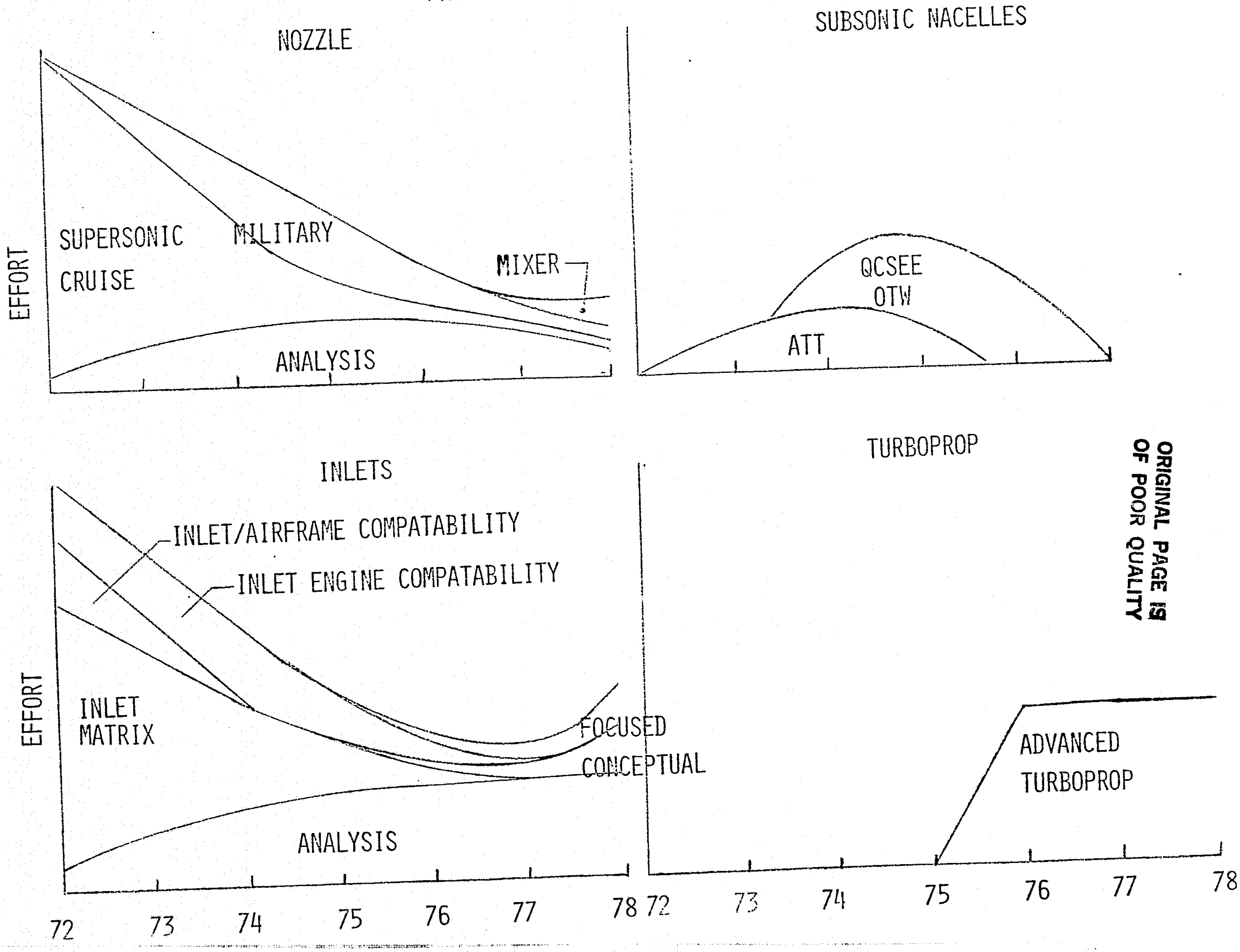
INLET AND NOZZLE RESEARCH
505-04-11

DESCRIPTION: ANALYTICAL AND EXPERIMENTAL DESIGN METHODOLOGY FOR THE INTERNAL FLOW OF INLETS AND NOZZLES TO ACHIEVE HIGHER PERFORMANCE WITH INCREASED PROPULSION SYSTEM STABILITY AND OPERATING RANGE IS BEING DEVELOPED.

TARGETS:

- ESTABLISH CRITERIA FOR PREDICTION OF DRAG ON BOATTAIL NOZZLES INCLUDING REYNOLDS NUMBER EFFECTS - FY 1978
- IDENTIFY STATISTICAL DISTORTION TECHNIQUES FOR THE PREDICTION OF PEAK INSTANTANEOUS INLET DISTORTION - FY 1980
- EVALUATE AUXILIARY AIRFLOW INLETS FOR VARIABLE CYCLE ENGINES - FY 1980
- ESTABLISH RATIONALE FOR PREDICTION OF INTERACTION EFFECTS OF NOZZLES ON AIRCRAFT PERFORMANCE - FY 1980
- EVALUATE A COMPUTER ANALYSIS OF THREE-DIMENSIONAL TRANSONIC INLET FLOWS AT HIGH ANGLE OF ATTACK - FY 1982
- DEVELOP A THREE-DIMENSIONAL ANALYSIS FOR THE FLOW IN A SUPERSONIC DIFFUSER OF GENERAL GEOMETRY - FY 1982

PROPULSION AERODYNAMICS BRANCH



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LEWIS PROPELLER AERODYNAMIC PROGRAM

OBJECTIVE: GENERATE THE TECHNOLOGY FOR MULTI-BLADED, HIGHLY EFFICIENT, HIGH SPEED PROPELLERS SUITABLE FOR USE ON ADVANCED TURBOPROP-POWERED AIRCRAFT OPERATING AT MACH 0.8 AND 30,000 FEET.

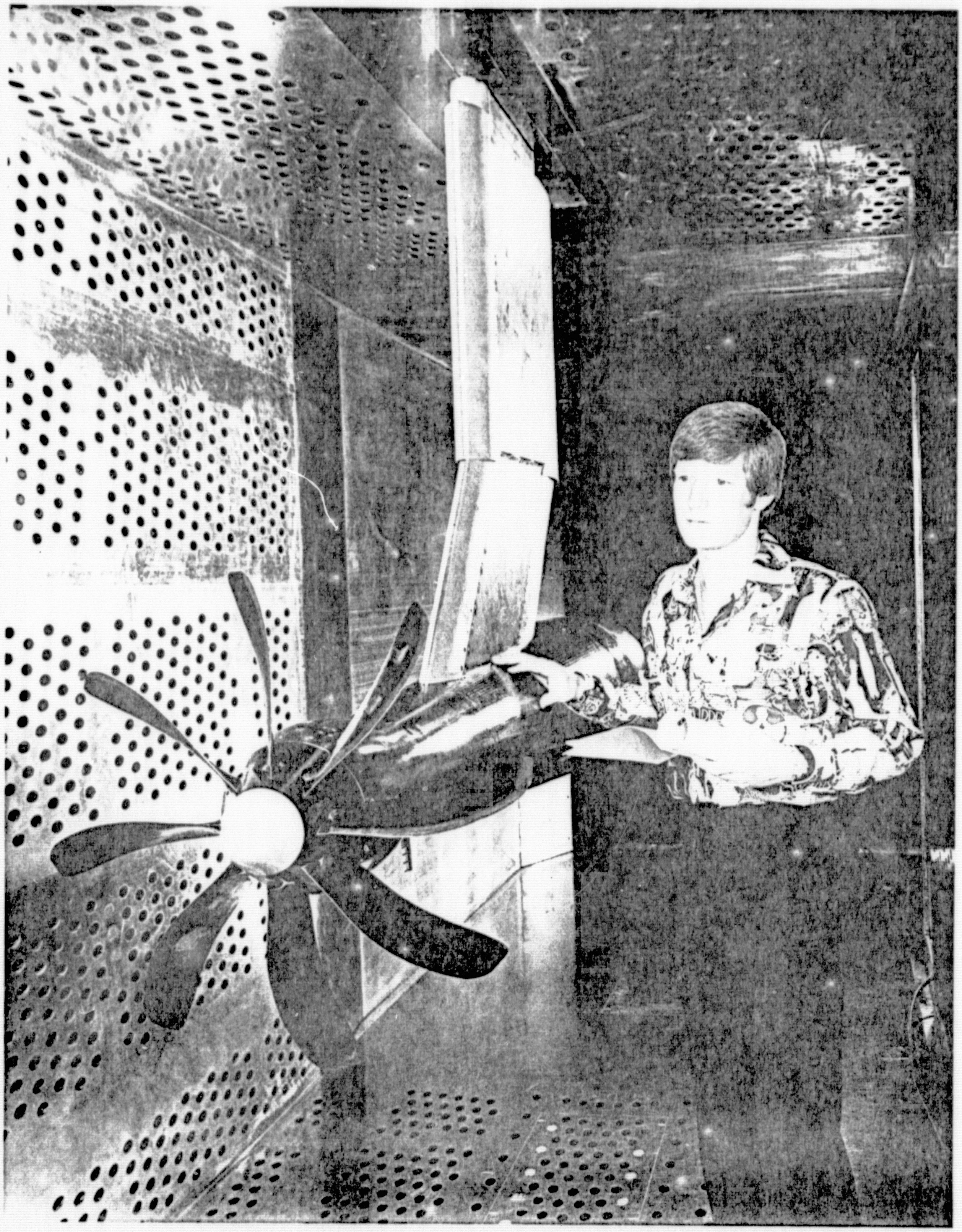
EXPERIMENTAL

- PROP. TEST RIGS - 1000 H.P., SR & CR
- HIGH SPEED MODELS - 8SR, 2CR
- LASER FLOW SURVEY

ANALYSIS

- CURRENT - MOD. GOLDSTEIN, COMPRESSOR, TRANSONIC NACELLE
- FUTURE - LIFTING LINE: SR & CR PROP/NACELLE
LIFTING SURFACE: TRANSONIC 3D

NASA
C-76-3429



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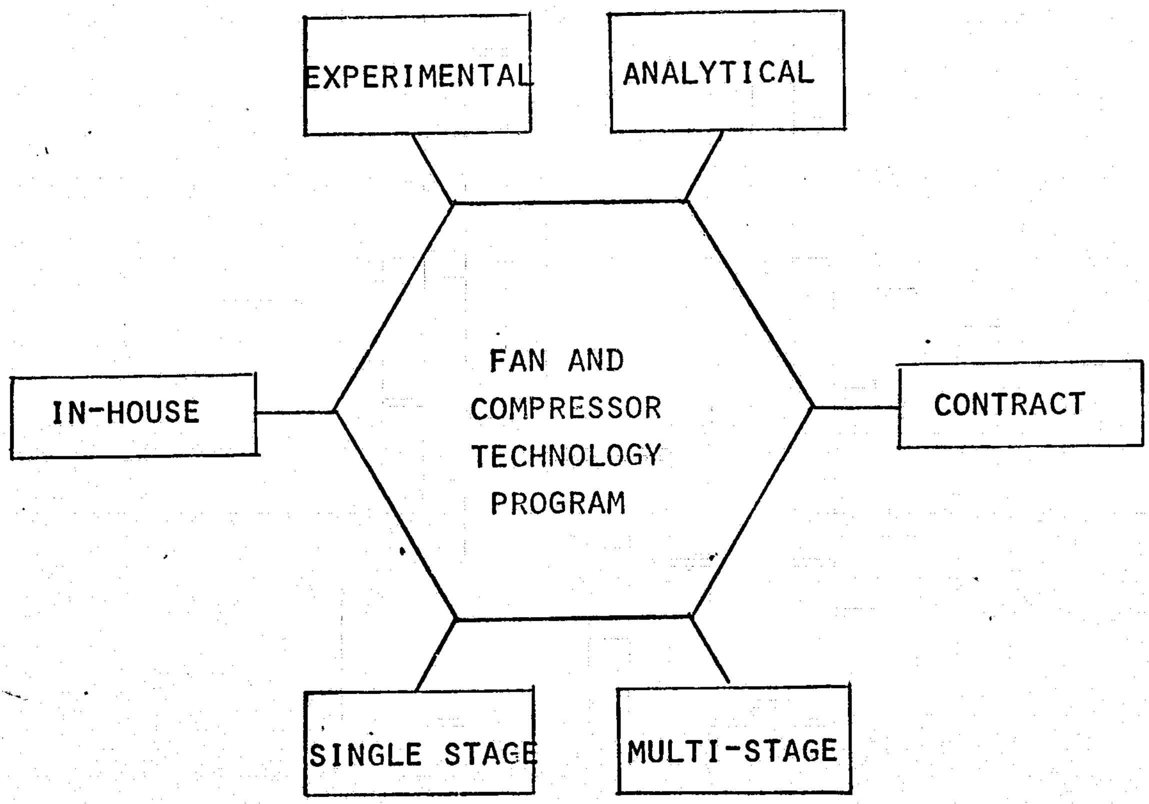
PROPULSION COMPONENTS R&T (RL)

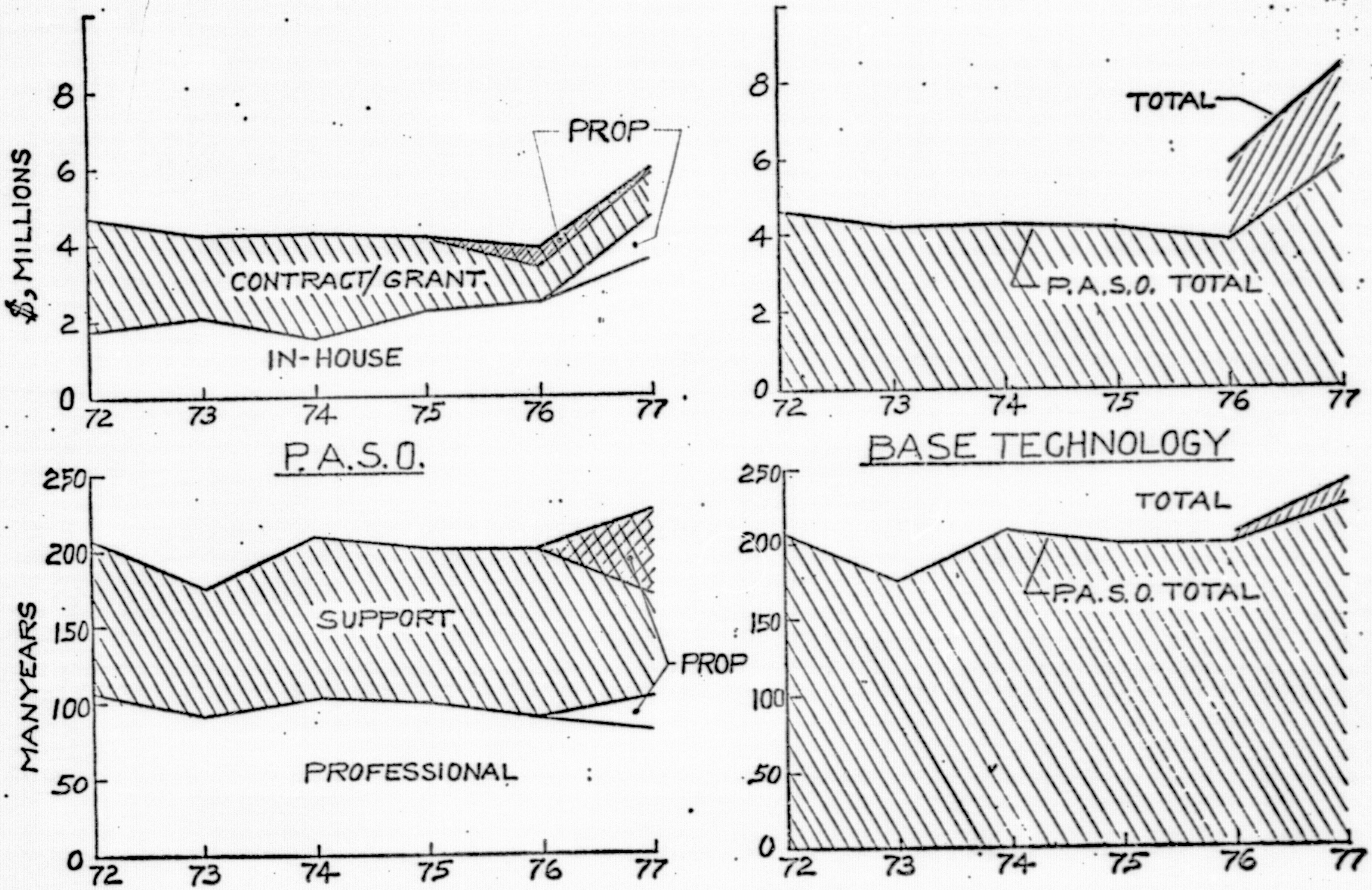
FAN, COMPRESSOR, AND TURBINE RESEARCH

FAN AND COMPRESSOR RESEARCH

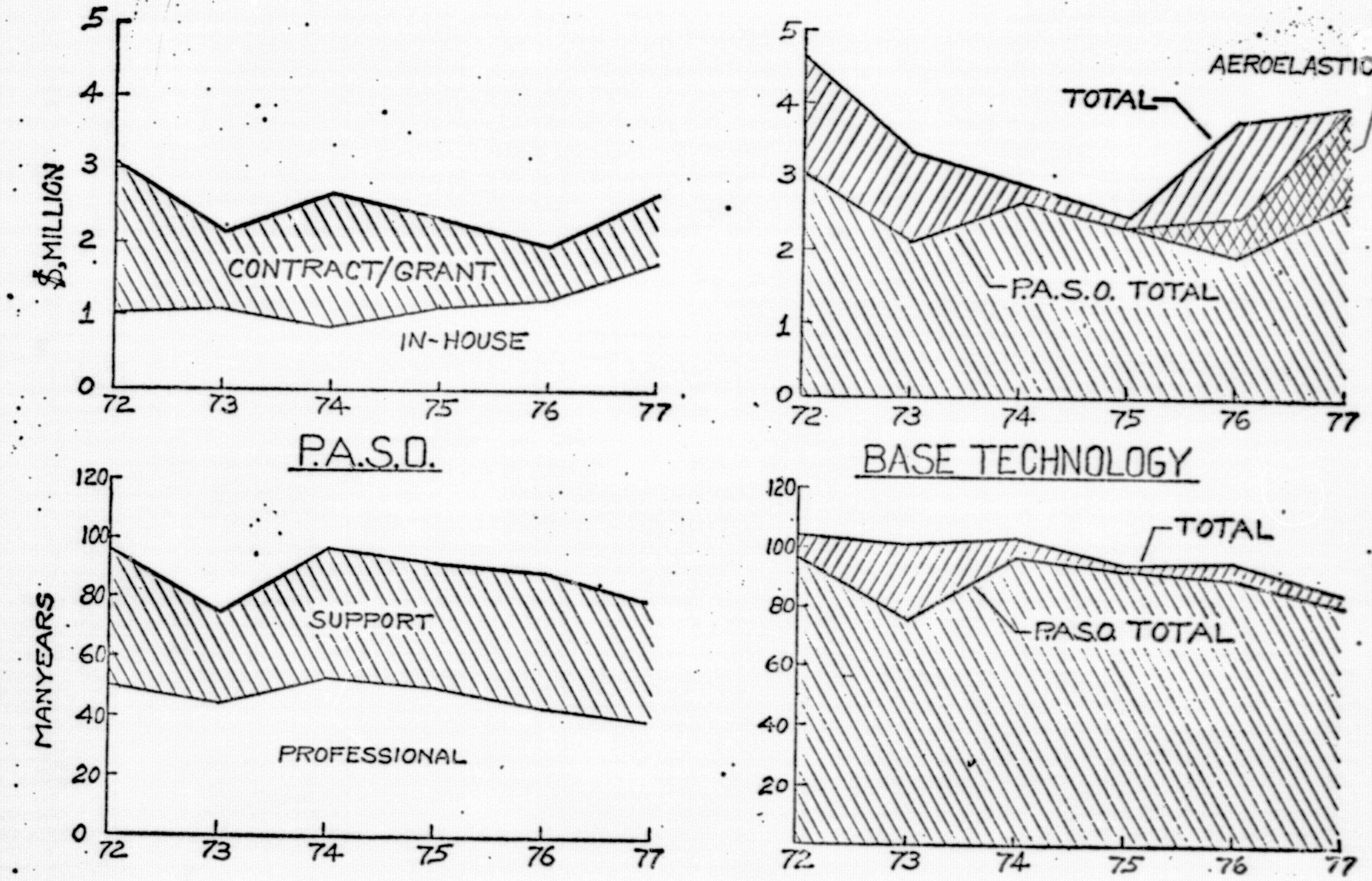
MELVIN J. HARTMANN, CHIEF
FAN AND COMPRESSOR BRANCH
FLUID SYSTEM COMPONENTS DIVISION



R&T TRENDS
PROPULSION COMPONENTS
FANS, COMPRESSORS, TURBINES, (PROPELLERS)



R&T TRENDS
FAN AND COMPRESSOR TECHNOLOGY



FAN AND COMPRESSOR BRANCH
ORGANIZATION

CHIEF, M. J. HARTMANN

SINGLE STAGE COMPRESSOR SECTION
HEAD, C. H. HAUSER

- CONDUCT AERO DESIGN, EXPERIMENTAL PERFORMANCE EVALUATION OF ADVANCED FAN, CORE COMPRESSOR STAGES.
- MAKE DETAILED FLOW MEASUREMENTS - HOLOGRAPHY, LASER VELOCIMETER.
- CONDUCT EXPERIMENTAL STUDIES OF SPECIAL DESIGN FEATURES - VARIABLE PITCH ROTORS, CASING TREATMENT.
- CONTRACT MONITOR/FAN FOR VCE.

PERSONNEL 7

MULTISTAGE COMPRESSOR SECTION
HEAD, C. L. BALL

- DEMONSTRATE TECHNOLOGY FOR DEVELOPMENT OF MULTISTAGE COMPRESSORS WITH REDUCED NUMBER OF STAGES, HIGH EFFICIENCY, A WIDE STABLE FLOW RANGE, FEWER PARTS, LOWER COST.
- DETERMINE THE CRITERIA FOR MATCHING HIGH PRESSURE STAGES IN MULTISTAGE ENVIRONMENT.

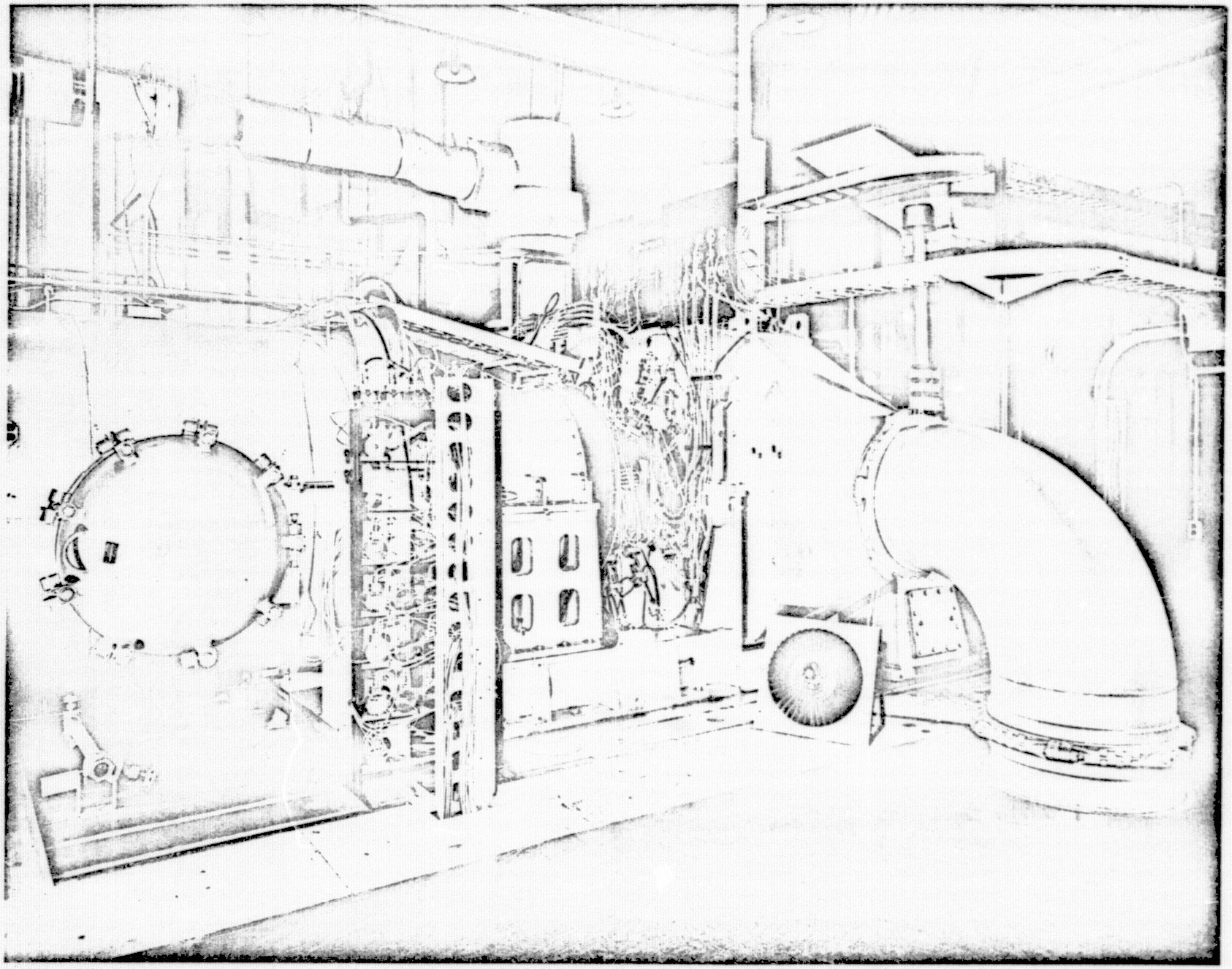
PERSONNEL 6
(PLUS 1 AAMRDL)

DESIGN AND ANALYSIS SECTION
HEAD, D. M. SANDERCOCK

- DEVELOP DESIGN/OFF-DESIGN PREDICTION SYSTEMS.
- DEVELOP ANALYTICAL "TOOLS" TO AID IN ANALYSIS OF EXPERIMENTAL RESULTS.
- CONDUCT ANALYTICAL PARAMETRIC STUDIES.
- DEVELOP UNSTEADY FLOW ANALYSIS CODES FOR PREDICTING BLADE FLUTTER.

PERSONNEL 8

NASA
C-72-364



SINGLE STAGE COMPRESSOR RESEARCH FACILITY

NASA
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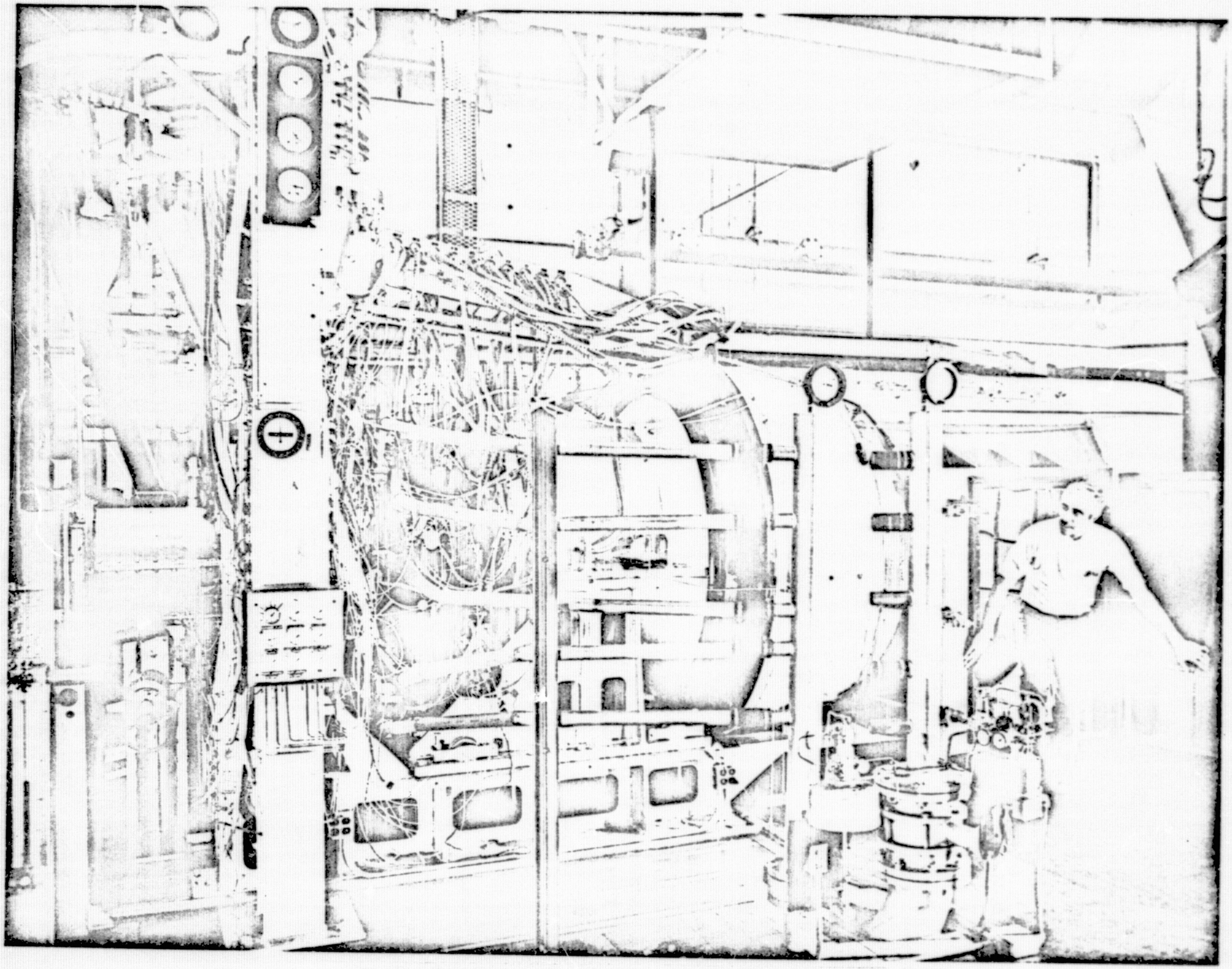

MULTI-STAGE COMPRESSOR RESEARCH FACILITY

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FAN AND COMPRESSOR TECHNOLOGY

OBJECTIVES:

- TO IMPROVE EFFICIENCY, OPERATING RANGE, DISTORTION TOLERANCE, DURABILITY, RELIABILITY, AND TO REDUCE WEIGHT, VOLUME, AND COST OF THE WIDE VARIETY OF FANS AND COMPRESSORS REQUIRED FOR ADVANCED PROPULSION SYSTEMS. IMPROVE ACCURACY OF PERFORMANCE PREDICTION TO REDUCE THE TIME, COST, AND RISK OF INCORPORATING ADVANCED FANS AND COMPRESSORS INTO FUTURE ENGINE DEVELOPMENT PROGRAMS.

TARGETS:

- DETERMINE METHODS OF MAINTAINING HIGH LEVELS OF FAN PERFORMANCE WHEN APPLYING LOW NOISE FAN DESIGN APPROACHES OR SOUND SUPPRESSION DEVICES - FY 1978.

- EVALUATE THE LIMITS OF PRESSURE RATIO FOR CORE COMPRESSOR STAGES (HUB/TIP RATIO 0.5 - 0.93) CONSISTENT WITH HIGH EFFICIENCY (85%) AND STALL MARGIN (10%) - FY 1978.

- DETERMINE THE CRITERIA FOR MATCHING HIGH PRESSURE RATIO STAGES IN ADVANCED MULTISTAGE COMPRESSORS - FY 1980.

- DETERMINE BLADE SHAPES AND TECHNIQUES SUCH AS SPECIAL TIP CLEARANCE PROVISIONS FOR ACHIEVING RETENTION OF PERFORMANCE OVER THE LIFE OF FANS AND COMPRESSORS - FY 1979.

- DEVELOP AND EVALUATE IMPROVED ANALYTICAL METHODS OF CALCULATING THREE-DIMENSIONAL FLOWFIELDS THROUGHOUT A COMPRESSOR - FY 1978.

- DEMONSTRATE THE TECHNOLOGY IN SMALL SINGLE-STAGE CENTRIFUGAL COMPRESSORS FOR ACHIEVING 10:1 PRESSURE RATIO WITH AN EFFICIENCY GREATER THAN 78% - FY 1980.

FAN BASE TECHNOLOGY

PROGRAM

PAST - HIGH MACH NUMBER BLADING

IN-HOUSE

- 1400 FT/SEC STAGES (25)
- LOW-NOISE DESIGNS
- TWO-STAGE FAN
- VARIABLE-PITCH FANS

CONTRACT

- 1000 FT/SEC STAGE (PWA)
- 1400 FT/SEC STAGE (GE)
- 1500 FT/SEC STAGE (GE)
- 1600 FT/SEC STAGE (PWA & AIRES)
- 1800 FT/SEC STAGE (PWA)
- LOW NOISE FANS (PWA & GE)

CURRENT

- CASING TREATMENT/TIP CLEARANCE (IH)
- VARIABLE-PITCH FAN (PR=1.35) (IH)
- LOW SOURCE NOISE FANS (IH)
- VCE FAN STUDY (GE)

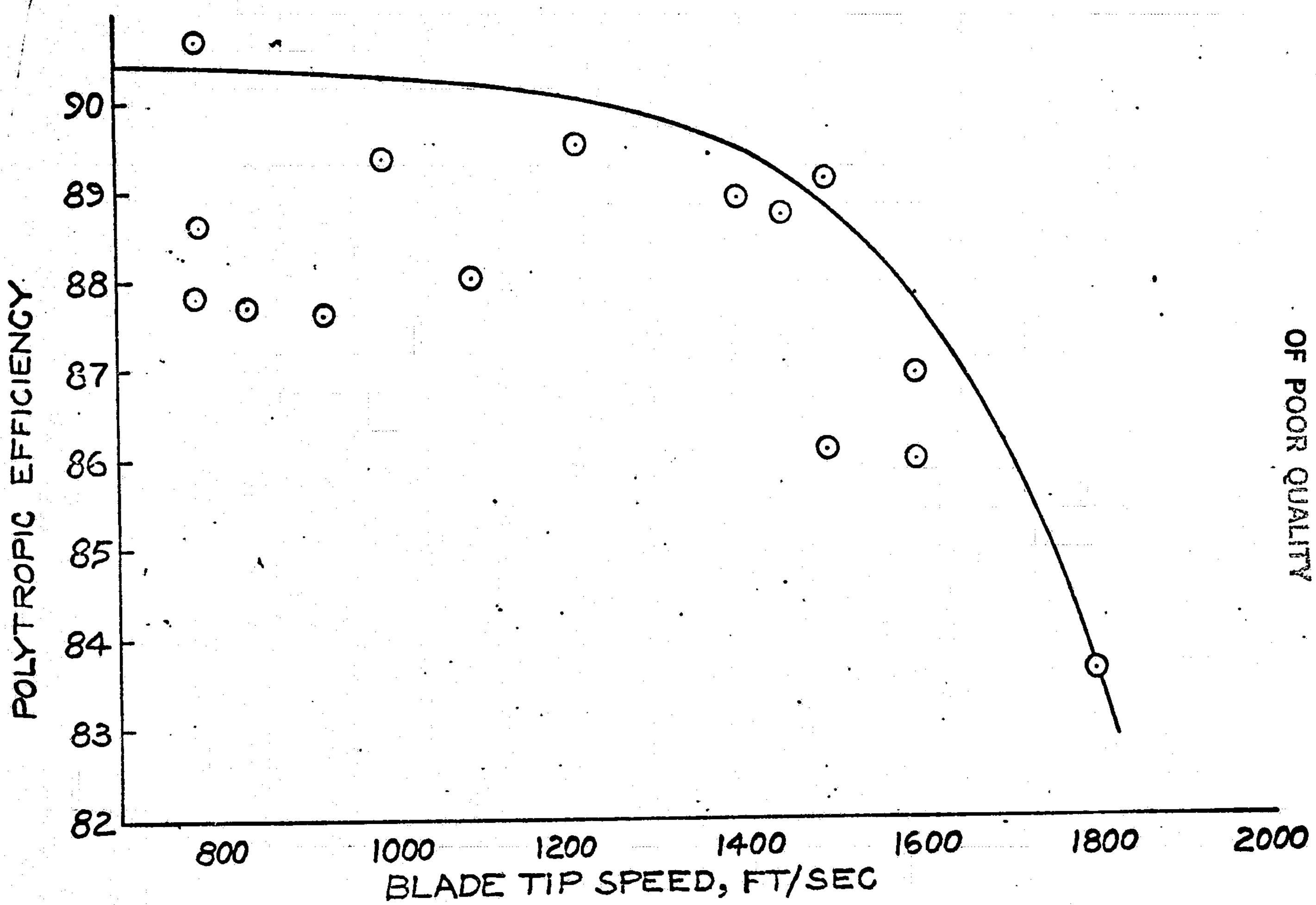
FUTURE

- IMPROVE HIGH-SPEED PERFORMANCE IN 1800-2000 FT/SEC RANGE
- OPTIMIZE FOR COMPOSITE BLADING
- REFINE EXISTING DESIGN SYSTEMS

APPLICATIONS

- BASIS OF DESIGN SYSTEMS FOR CURRENT FANS
- DIRECT APPLICATIONS
  - MCA BLADE SHAPES
  - CASING TREATMENT (JT9D)
  - TRANSONIC ROTOR PERFORMANCE (CF-6)
  - TWO-STAGE FAN (APSI & EXP. FAN)
  - SCALED 1600 FT/SEC FAN
  - LOW SPEED FAN

SINGLE STAGE FAN/COMPRESSOR EFFICIENCIES



COMPRESSOR BASE TECHNOLOGY

PROGRAM

PAST

- ADVANCED MULTISTAGE AXIAL FLOW COMPRESSOR (AMAC) (GE & PWA)
- LOW ASPECT RATIO (IH & PWA)
- BLUNT LEADING EDGE (IH)
- CASING TREATMENT-TIP CLEARANCE STUDY (IH)

CURRENT

- SINGLE STAGE STUDIES (INLET, MIDDLE, EXIT) (IH)
- INLET STAGE GROUPS (IH)
- EXIT STAGE GROUPS (GE & PWA)

FUTURE

- ADVANCED CORE COMPRESSORS (~20-1 PR)
- PERFORMANCE RETENTION

APPLICATIONS

- AMAC STUDY
- DESIGN CODES
- FLOW BLOCKAGE TECHNIQUES FOR MATCHING AXIAL-CENTRIFUGAL COMPRESSORS

NASA
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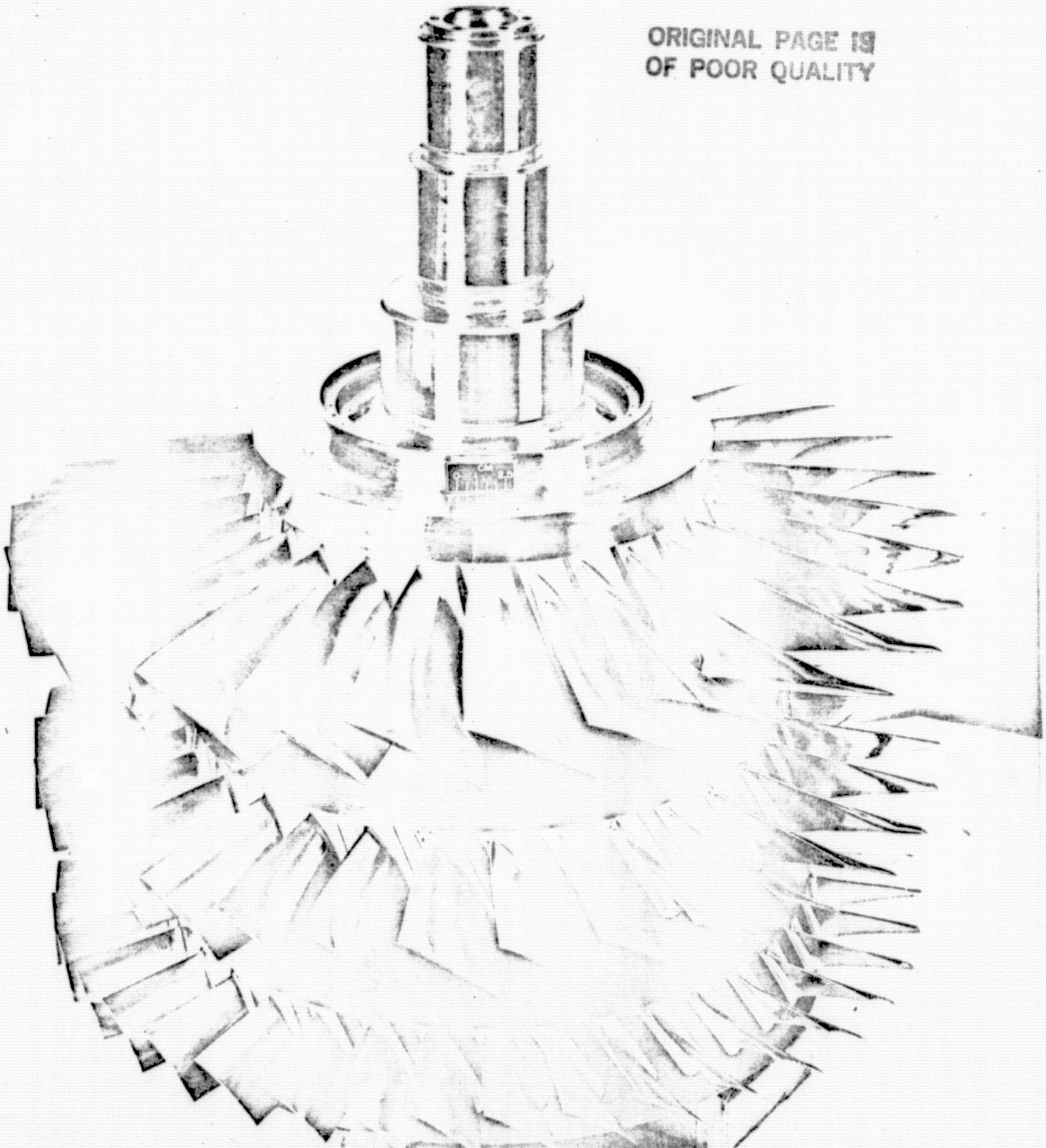


LOW ASPECT RATIO COMPRESSOR BLADING

DESIGN/ANALYSIS SYSTEMS

DEVELOP CODES VERIFICATION DESIGN METHODOLOGY

PAST		
• AXISYMMETRIC DESIGN CODE - DATA BANK		I.H.
• 2D SUBSONIC INVISCID FLOW CODES	(HUB-TO-SHROUD) (BLADE-TO-BLADE)	I.H.
• 2D BOUNDARY LAYER FLOW CODES		I.H.
• SHOCK CONFIGURATION	(DYNAMIC PRESSURE) (HOLOGRAPHY)	I.H. & C
CURRENT		
• AXISYMMETRIC OFF-DESIGN PERFORMANCE CODE		I.H.
• 2D TRANSONIC INVISCID FLOW CODES	(HUB-TO-SHROUD) (BLADE-TO-BLADE)	ATL
• 2D TRANSONIC PERTURBATION CODES	(SHORT-RUNNING)	NIELSEN ENG.
• 3D BOUNDARY LAYER (END WALL) FLOW CODE		I.H.
• 3D TRANSONIC INVISCID FLOW CODES	(LONG-RUNNING)	MIT
• 3D VISCOUS FLOW CODE	(LONG RUNNING)	THERMO MECH. SYS.
• FLOW DENSITY - GAS FLUORESCENT		MIT
• TRANSONIC FLOW VERIFICATION		MIT
FUTURE		
• 3D VISCOUS FLOW CODE	(SHORT RUNNING)	C
• FLOW VERIFICATION - INTERNAL FLOW MEASUREMENTS		I.H. & C
• INTEGRATION OF CODES INTO A DESIGN METHODOLOGY		
• 2D UNSTEADY FLOW CODES		

SMALL CENTRIFUGAL COMPRESSOR TECHNOLOGY

PAST

- 6:1 CONENTIONAL BACKSWEPT IMPELLER/VANED-ISLAND DIFFUSER (AIRESEARCH/IH)
- 6:1 TANDEM BACKSWEPT IMPELLER/TANDEM CASCADE DIFFUSER (AIRESEARCH/IH)

CURRENT

- 3:1 MIXED-FLOW FIRST STAGE OF 10:1 TWO-STAGE (AIRESEARCH/IH)
- 6:1 RADIAL BLADED IMPELLER WITH VARIOUS DIFFUSER DESIGNS (IH)
- 8:1 BACKSWEPT IMPELLER (SINGLE STAGE) (IH)
- LDV FLOW MEASUREMENTS/3D COMPUTER CODE VERIFICATION (CREARE)

FUTURE

- 6:1 RADIAL-BLADED IMPELLER WITH SPLITTERS (IH)
- 8:1 BACKSWEPT IMPELLER WITH SPLITTERS (IH)
- DIFFUSER GEOMETRY STUDIES (IH)

AEROELASTIC PROGRAM NASA/AFAPL

CURRENT

- FLUTTER BOUNDARY MAPPING
- INSTRUMENTATION
- UNSTEADY AERO ANALYSIS AND EXPERIMENTAL MODELING
- STRUCTURAL DYNAMICS AND EXPERIMENTAL MODELING
- AERO/STRUCTURAL INTEGRATION

FUTURE

- AEROELASTIC "TAILORING"
- FLUTTER COMPENDIUM
- FORCED VIBRATIONS
- AERO/STRUCTURAL DYNAMICS

FAN AND COMPRESSOR BASE TECHNOLOGY

CLOSING COMMENTS

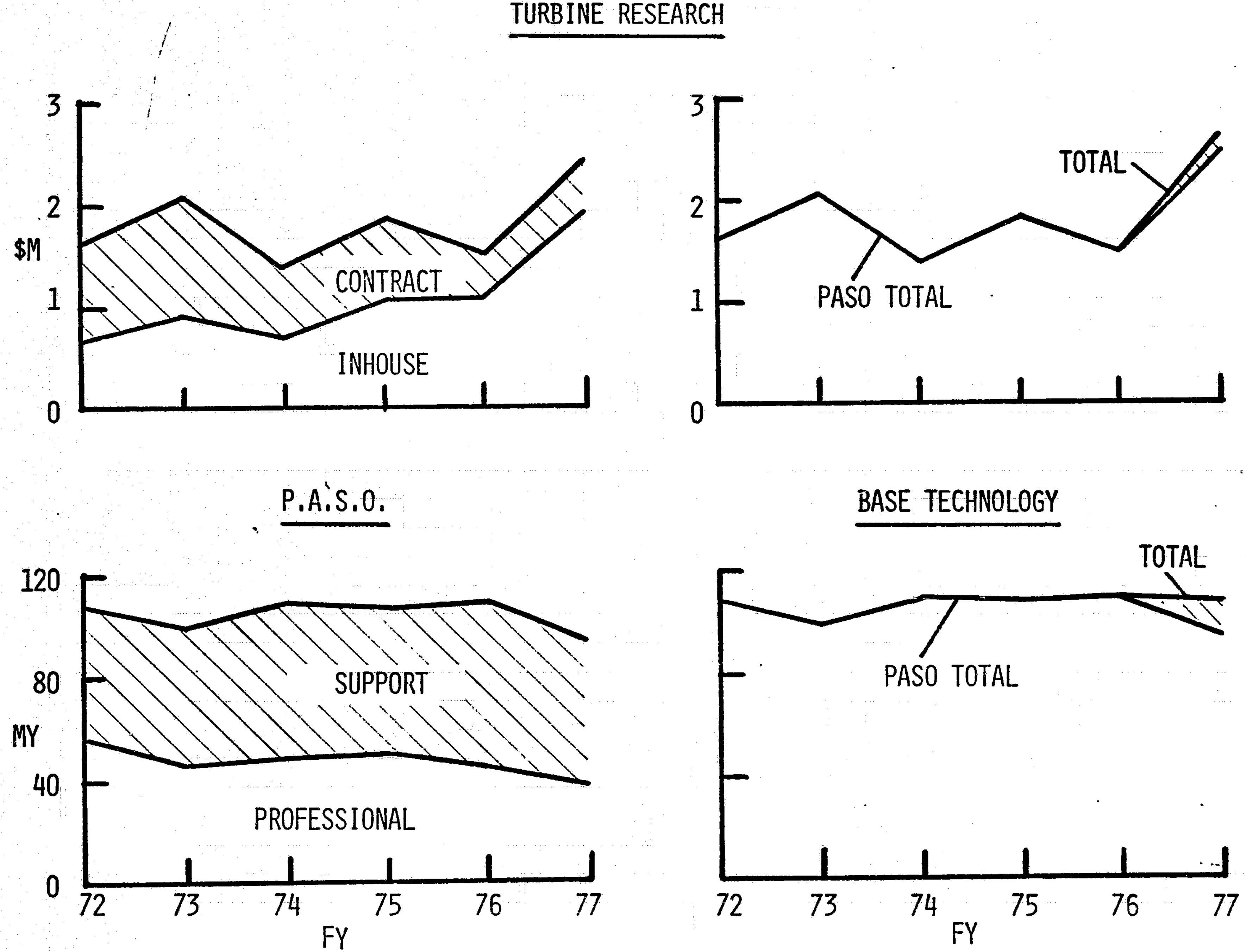
- PROGRAM MUST PROVIDE THE ADVANCED DATA BASE, THE DESIGN/ANALYSIS METHODS, AND THE NEW IDEAS IN THE PUBLIC DOMAIN.
- EXTENDING THE FLOW AND DYNAMIC ANALYSIS METHODS PROVIDES A POTENTIAL FOR REDUCING THE COST OF INTRODUCING ADVANCED MACHINERY.
- PRESENT TREND EMPHASIZES NEAR TERM APPLICATIONS AT THE EXPENSE OF BUILDING THE LONG TERM DATA BASE.
- AN EFFECTIVE BALANCE BETWEEN INHOUSE AND CONTRACT EFFORTS MUST BE MAINTAINED.
- PRESENT STAFF SIZE LIMITS INHOUSE AND CONTRACT PROGRAMS SUCH THAT TARGET DATES MAY NOT BE ACHIEVED.

TURBINE RESEARCH

IMPROVEMENT OF TURBINE LIFE, TURBINE PERFORMANCE, AND TURBINE DESIGN METHODS

HAROLD E. ROHLIK
CHIEF
TURBINE BRANCH

R & T TRENDS


TURBINE RESEARCH
3
2
1
0
$M
CONTRACT
INHOUSE
TOTAL
PASO TOTAL
P.A.S.O.
BASE TECHNOLOGY
120
80
40
0
MY
SUPPORT
PROFESSIONAL
TOTAL
PASO TOTAL
72
73
74
75
76
77
FY

TURBINE BRANCH

- **SMALL TURBOMACHINERY SECTION**
  - CENTRIFUGAL COMPRESSORS
  - SMALL AXIAL TURBINES
  - RADIAL TURBINES
  - HELICOPTER COMPONENTS
  - AUTOMOTIVE COMPONENTS
- **TURBOMACHINERY FUNDAMENTALS SECTION**
  - FLOW ANALYSIS
  - HEAT TRANSFER
  - LIFE PREDICTION
  - CASCADE EXPERIMENT
- **LARGE TURBINE AERODYNAMICS SECTION**
  - CORE TURBINES
  - FAN DRIVE TURBINES
- **TURBINE COOLING SECTION**
  - HOT CASCADES
  - HOT TURBINES
  - UTILITY GAS TURBINES

TURBINE RESEARCH

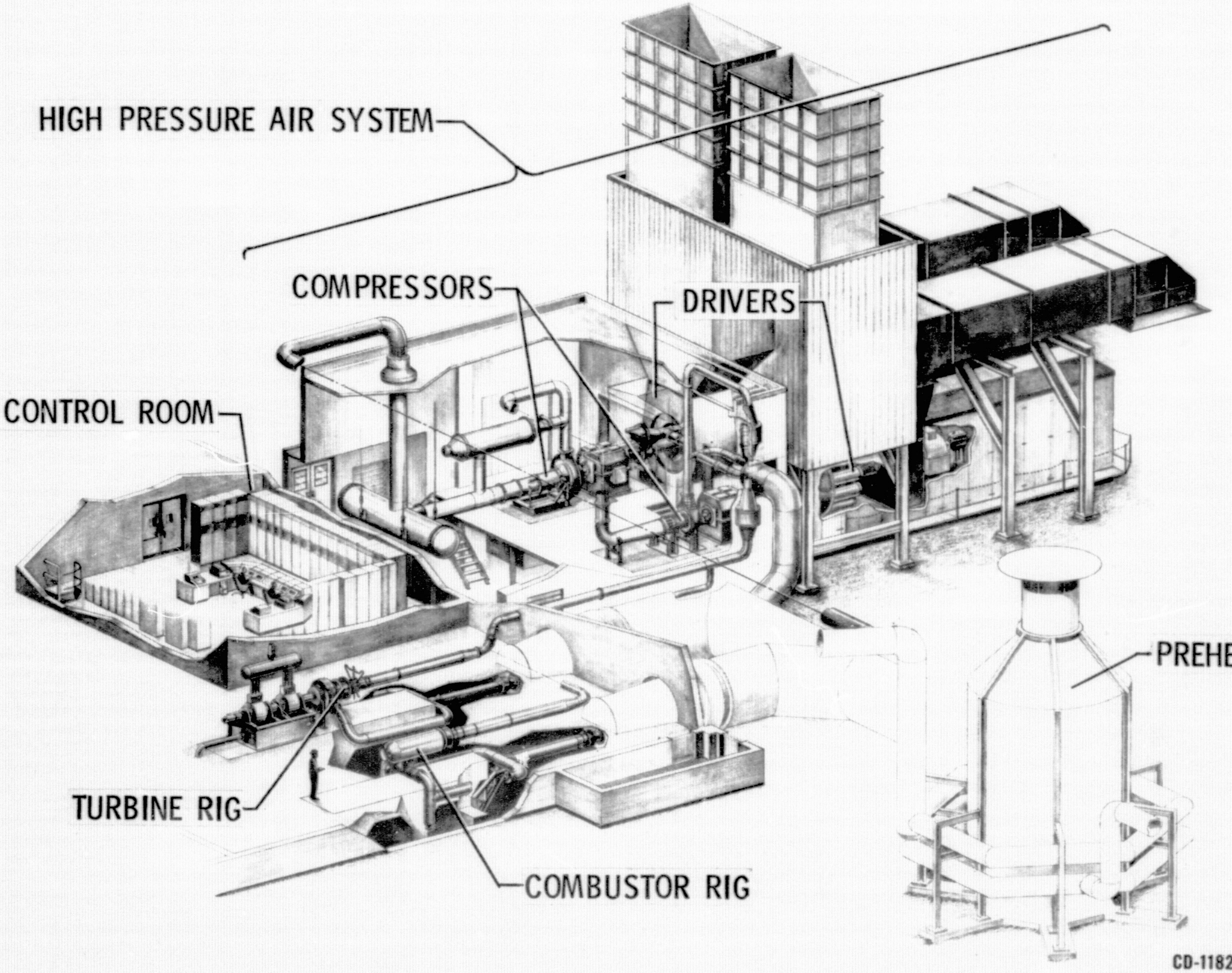
SPECIALIZED WORK AREAS	KEY PERSONNEL
AERODYNAMIC PERFORMANCE	T. P. MOFFITT R. Y. WONG W. J. WHITNEY R. J. ROELKE
COOLED-BLADE HEAT TRANSFER	R. S. COLLADAY F. S. STEPKA R. P. COCHRAN R. E. GAUGLER
INTERNAL FLOW ANALYSIS	T. KATSANIS L. J. GOLDMAN
HOT PART LIFE PREDICTION	A. KAUFMAN

TURBINE TEST CAPABILITY

TEMPERATURE °F	DIAMETER INCHES	SPEED RPM	USE
COLD	6	100,000	AERO
COLD	12	30,000	AERO
COLD	30	6,000	AERO
● 1000	20	15,000	AERO (THERMO)
● 4000	20	22,000	AERO (THERMO)

● BEING CONSTRUCTED

HIGH PRESSURE FACILITY



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TURBINE RESEARCH

STATEMENT OF OBJECTIVE

IMPROVEMENT OF LIFE, PERFORMANCE, AND DESIGN METHODS FOR AXIAL AND RADIAL TURBINES.

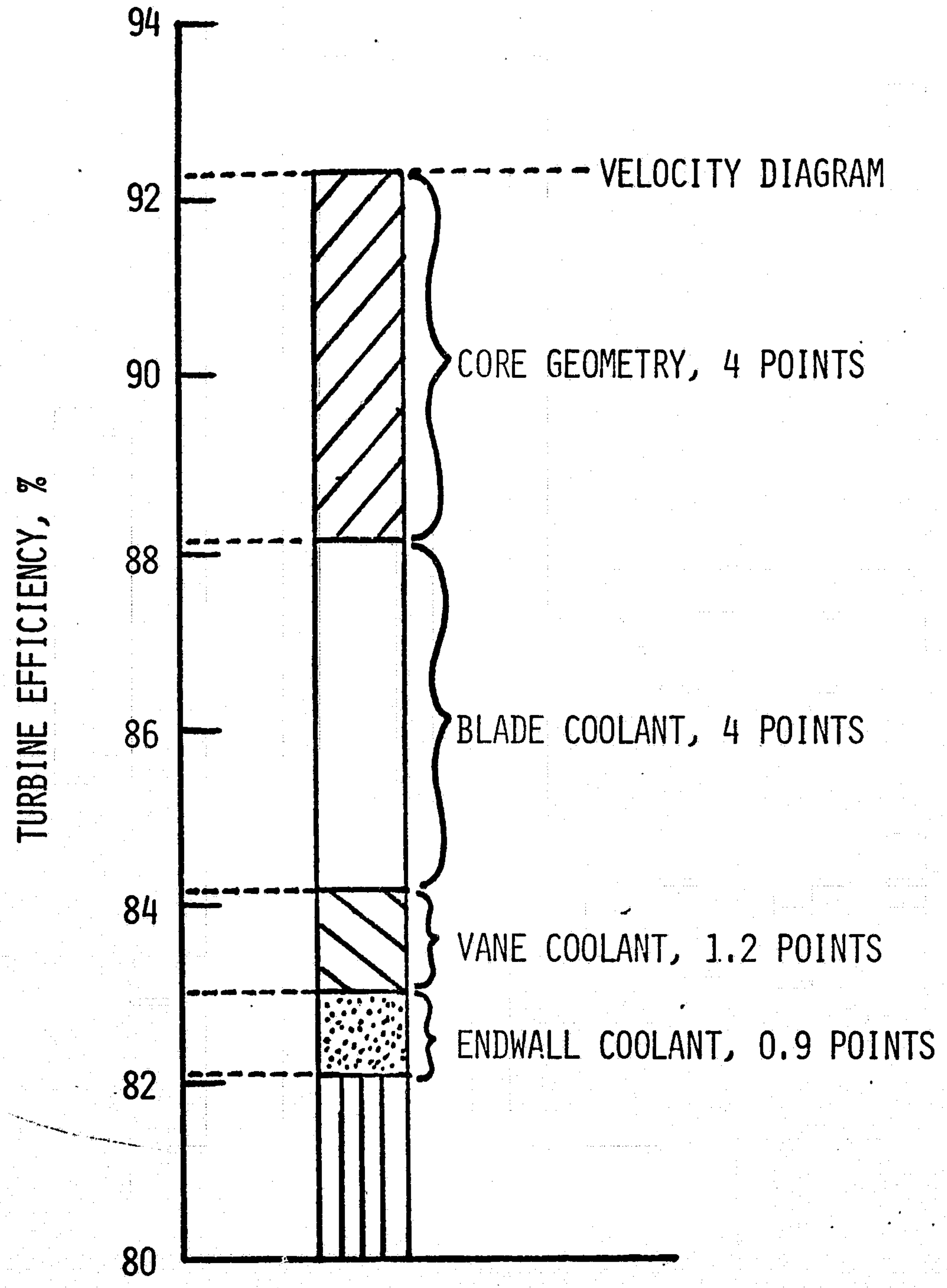
TARGETS

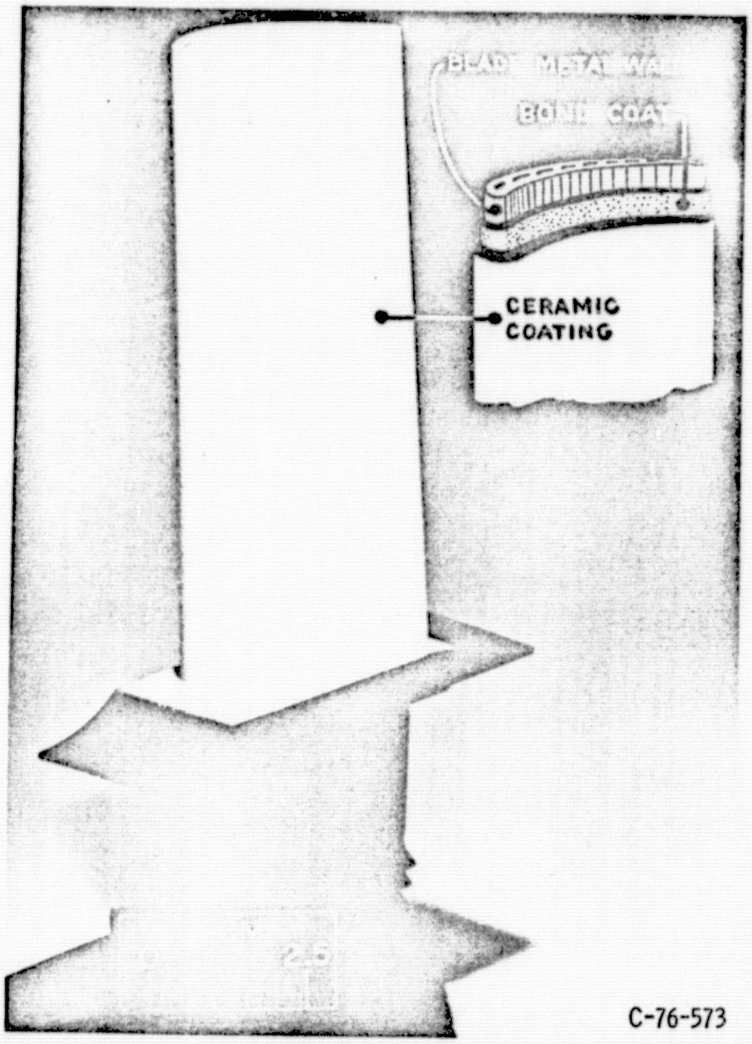
- DETERMINE LEVELS OF EFFICIENCY AND AERODYNAMIC EFFECTS OF COOLING IN ADVANCED SINGLE AND TWO-STAGE CORE TURBINES - FY 1979

- DETERMINE MINIMUM COOLANT FLOW REQUIREMENTS AND MINIMUM AERODYNAMIC PENALTIES FOR THE VERY HIGH-PRESSURE, HIGH-TEMPERATURE OPERATING CONDITIONS - FY 1980

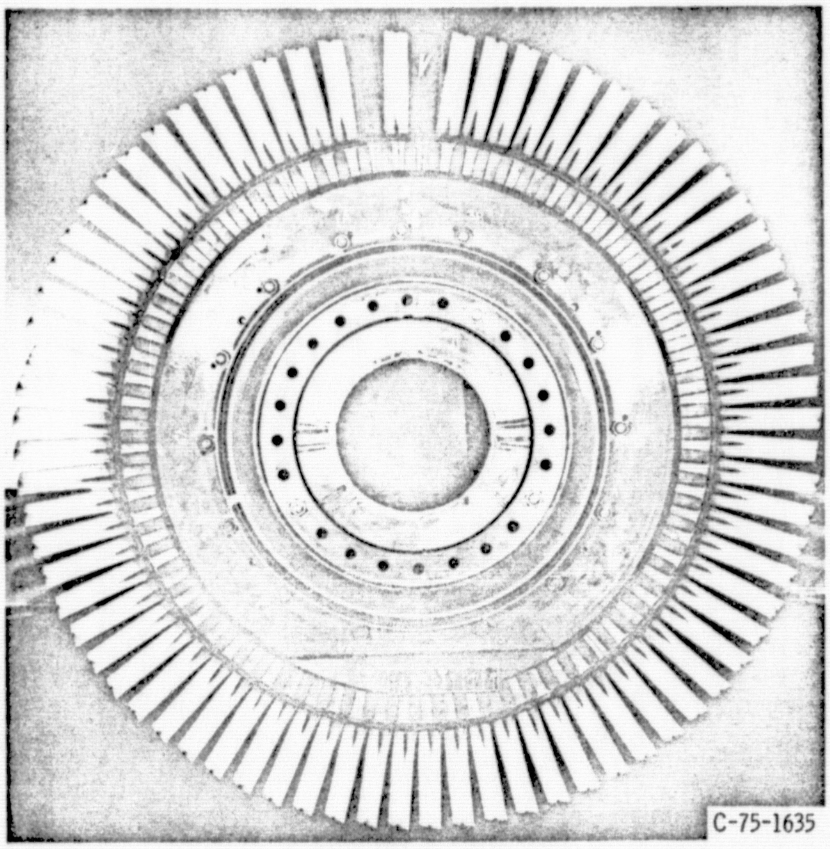
- DEVELOP ANALYTICAL ABILITY TO PREDICT (1) METAL TEMPERATURES IN TURBINE VANES, BLADES AND END WALLS WITH VERY HIGH HEAT FLUXES AND COMPLEX COOLANT FLOWS AND BLADE CONFIGURATIONS, (2) AERODYNAMIC PERFORMANCE WITH VARIOUS COOLING AIR DISCHARGE LOCATIONS, SECONDARY FLOWS, TIP CLEARANCE AND END WALL LOSSES, AND (3) CYCLIC STRESS DISTRIBUTIONS FOR LOW-CYCLE FATIGUE BLADE LIFE EVALUATION - FY 1981

CORE TURBINE LOSSES





- Ceramic coated turbine blade.



· Ceramic coated blades after 500 cycles of testing.

MAJOR CONTRIBUTIONS - TURBINES

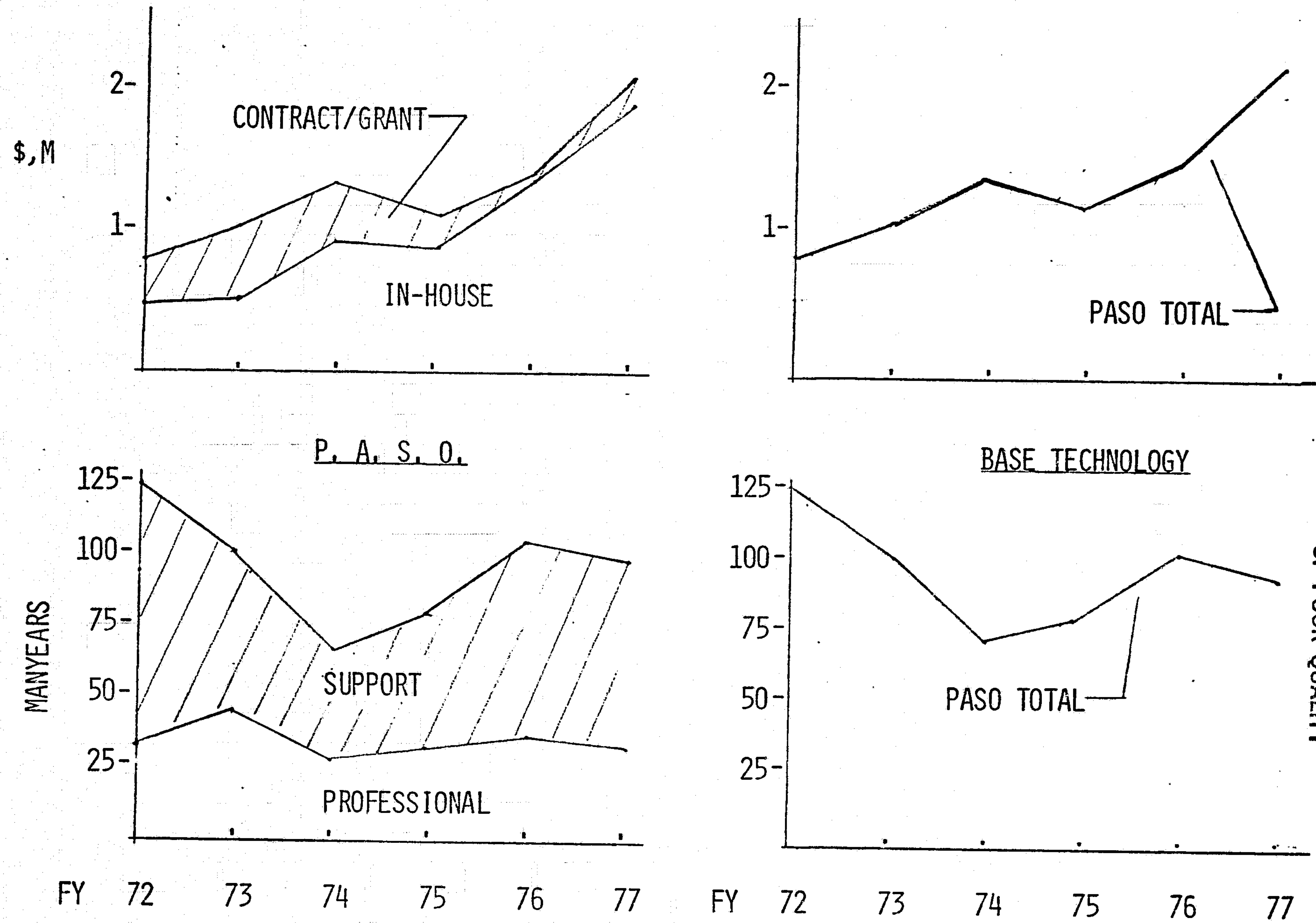
- THERMAL BARRIER COATINGS
- HIGH STAGE WORK FACTOR TURBINES
- PNEUMATIC VARIABLE GEOMETRY USING JET-FLAP BLADING
- AERO AND THERMO DESIGN COMPUTER PROGRAMS

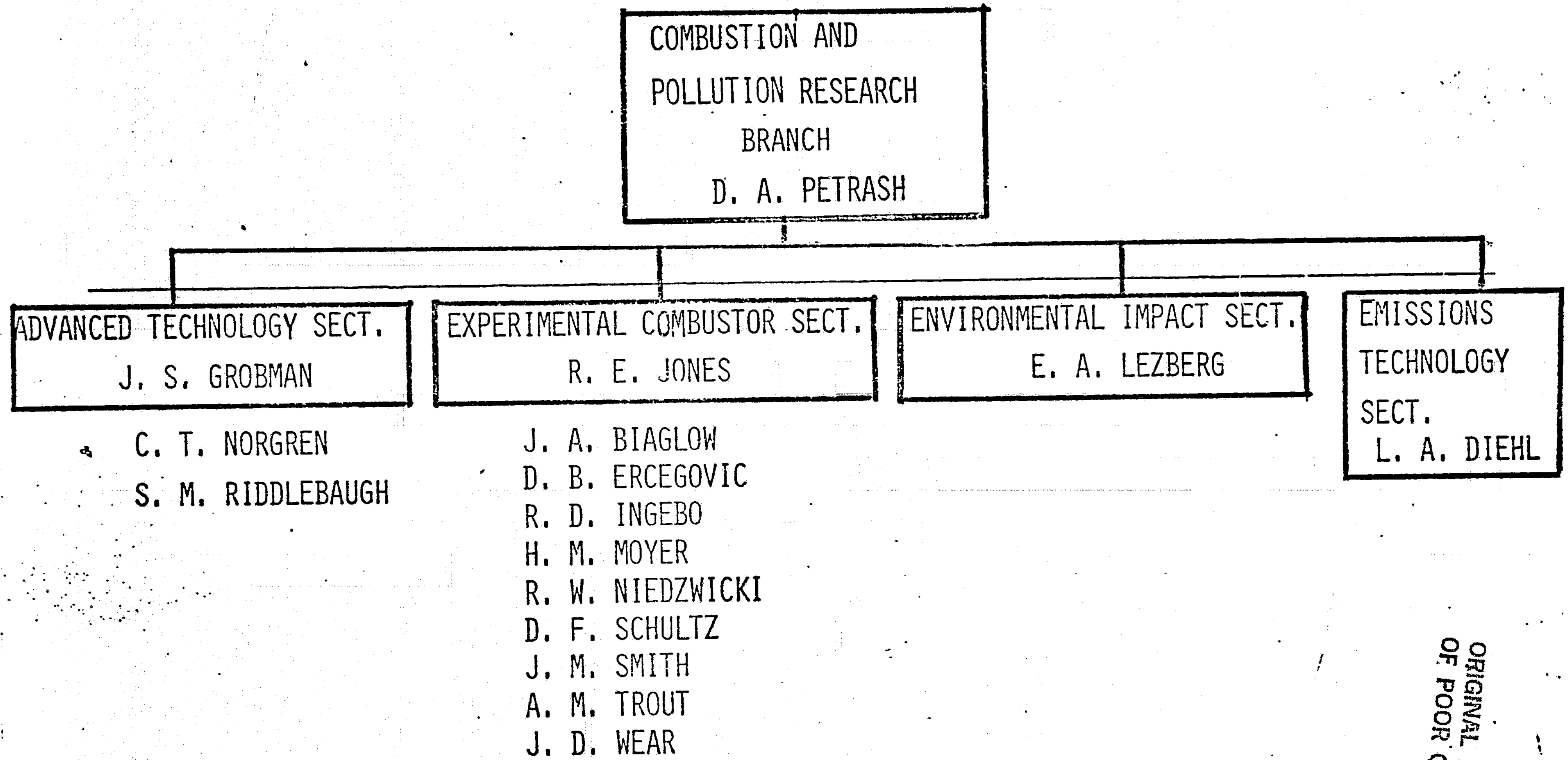
PROPULSION COMPONENTS

COMBUSTION AND AUGMENTATION SYSTEM RESEARCH

DONALD A. PETRASH - AIRBREATHING ENGINES DIVISION

R & T TRENDS
COMBUSTION AND AUGMENTATION SYSTEMS

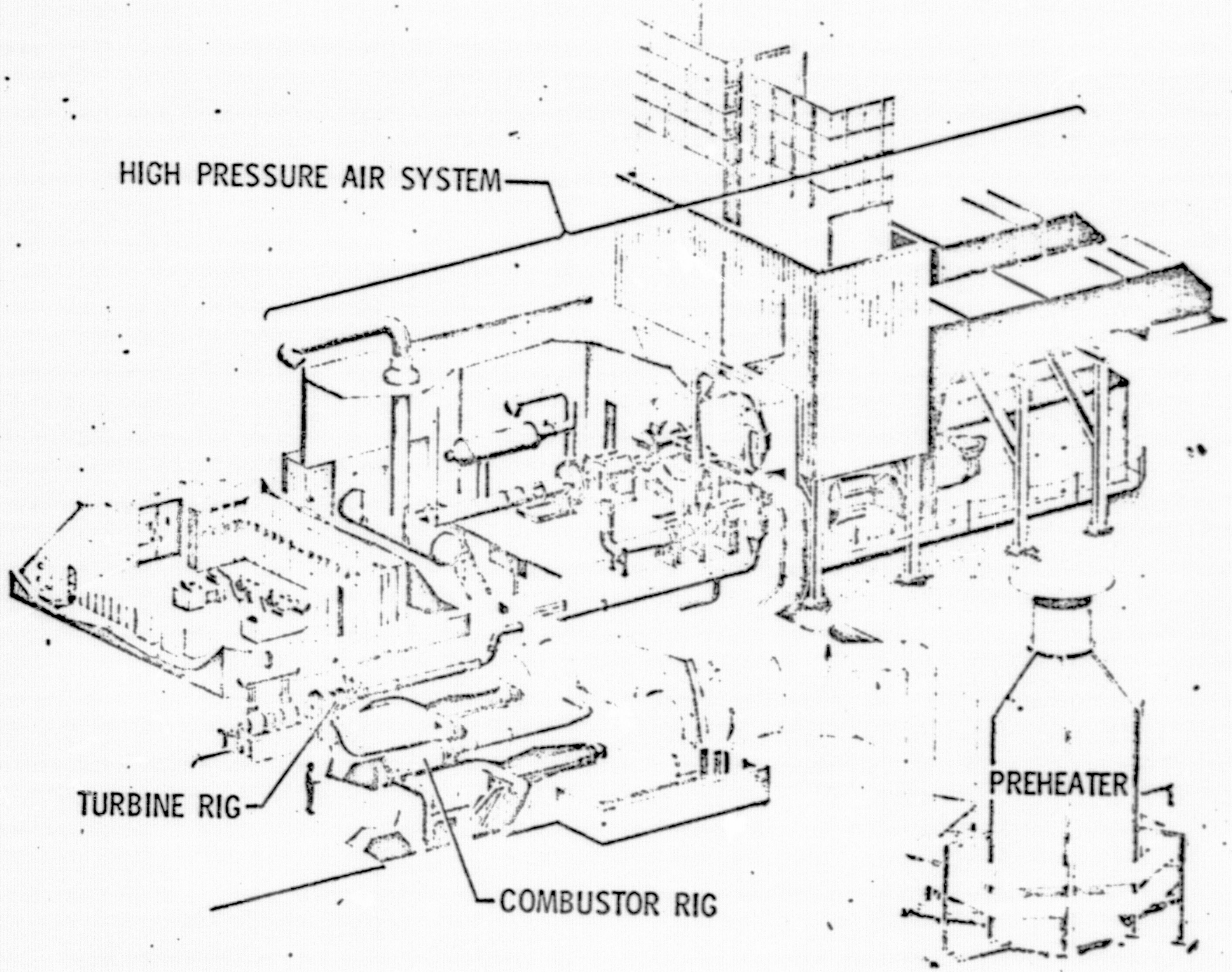



COMBUSTION AND POLLUTION RESEARCH BRANCH
D. A. PETRASH
ADVANCED TECHNOLOGY SECT.
J. S. GROBMAN
C. T. NORGREN
S. M. RIDDLEBAUGH
EXPERIMENTAL COMBUSTOR SECT.
R. E. JONES
J. A. BIAGLOW
D. B. ERCEGOVIC
R. D. INGEBO
H. M. MOYER
R. W. NIEDZWICKI
D. F. SCHULTZ
J. M. SMITH
A. M. TROUT
J. D. WEAR
ENVIRONMENTAL IMPACT SECT.
E. A. LEZBERG
EMISSIONS TECHNOLOGY SECT.
L. A. DIEHL

RESEARCH FACILITIES

FACILITY	AIR FLOW RATE, LB/SEC	PRESSURE, PSIA	TEMPERATURE, °F
ORL-12	15	15	AMBIENT
CE-5B, B	5	30	1150
CE-5M	35	450	250
CE-9B, A	35	450	950
ECRL-1	110	120	1150
HPF	187	600	1150

HIGH PRESSURE–HIGH TEMPERATURE TURBINE FACILITY



CS-73557

PROPULSION COMPONENTS R&T

SPECIFIC

OBJECTIVE: COMBUSTOR AND AUGMENTATION SYSTEM RESEARCH

STATEMENT OF OBJECTIVE

EXPERIMENTAL RESEARCH IS CONDUCTED ON SCALE MODELS AND FULL SCALE COMBUSTORS AND AUGMENTORS EXPLORING MEANS FOR IMPROVING DURABILITY AT HIGH TEMPERATURES AND PRESSURES.

TARGET:

- EXPERIMENTALLY DEMONSTRATE ADVANCED COMBUSTOR CONCEPTS CAPABLE OF EFFICIENT AND DURABLE OPERATION AT PRESSURES FROM 12-40 ATMOSPHERES AND DISCHARGE TEMPERATURES UP TO 4000° F FY 1981.

- EXPERIMENTALLY DEMONSTRATE THE ABILITY OF SELECTED COMBUSTOR CONCEPTS TO PROVIDE EFFICIENT (100%) COMBUSTION AND DURABLE OPERATION FOR SMALL GAS TURBINE (< 1000 SHP) SHAFT POWER ENGINES - FY 80.

TARGET: EXPERIMENTALLY DEMONSTRATE ADVANCED COMBUSTOR CONCEPTS CAPABLE OF EFFICIENT AND DURABLE OPERATION AT PRESSURES FROM 12 TO 40 ATMOSPHERES AND DISCHARGE TEMPERATURES UP TO 4000^{o} F FY 1981.

PRINCIPAL PROGRAM ELEMENTS:

IN-HOUSE

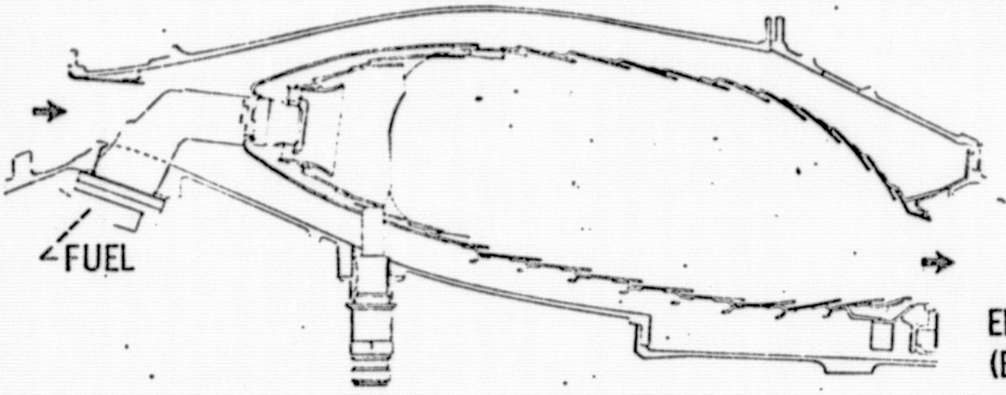
- HIGH PRESSURE COMBUSTOR PROGRAM
- ADVANCED HIGH PRESSURE, HIGH TEMPERATURE COMBUSTOR CONCEPTS
  - SWIRL-FLOW
    TWO-ZONE
    RICH-BURNING
    VARIABLE GEOMETRY
- FUEL INJECTION TECHNIQUES

CONTRACT/GRANT

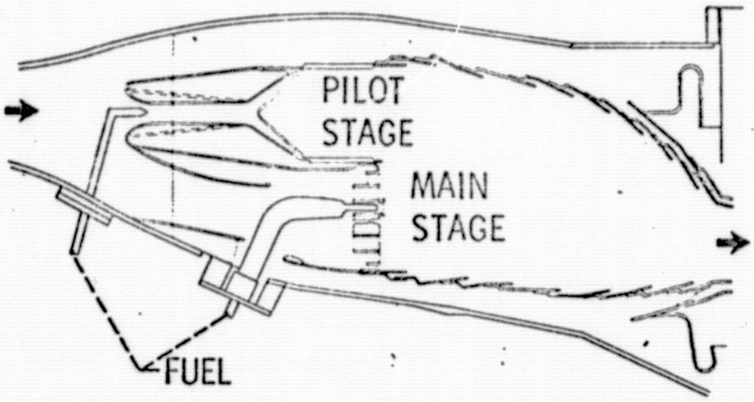
- EMISSION PARAMETERS OF GAS TURBINE ENGINES
  (UN. OF CINC.)
- TRANSPIRATION COOLED HIGH PRESSURE, HIGH TEMPERATURE LINER (DDA)

EXPERIMENTAL CLEAN COMBUSTOR PROGRAM

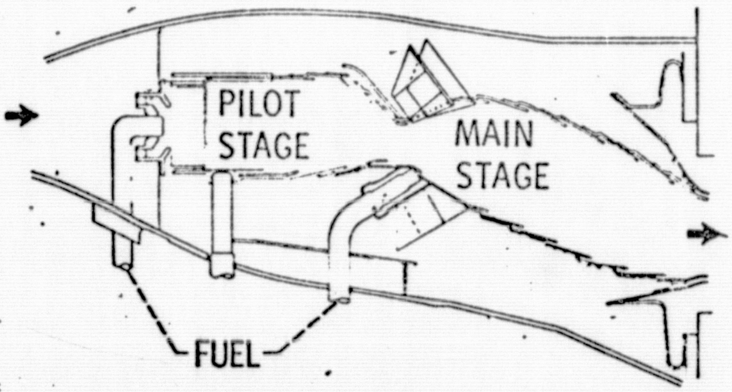
T2 CLASS, JT9D-7 ENGINE



ENGINE CONVENTIONAL
(BASELINE) COMBUSTOR



HYBRID CONCEPT



VORBIX CONCEPT

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TARGET: EXPERIMENTALLY DEMONSTRATE THE ABILITY OF SELECTED COMBUSTOR CONCEPTS TO PROVIDE EFFICIENT (100%) AND DURABLE OPERATION FOR SMALL GAS TURBINE ($<$ 1000 SHP) SHAFT POWER ENGINES - FY 1980.

PRINCIPAL PROGRAM ELEMENTS:

IN-HOUSE

- SMALL REVERSE-FLOW COMBUSTOR PROGRAM
  - FUEL INJECTION TECHNIQUES
  - LINER COOLING
  - LINER DURABILITY TO 3000^{o}F

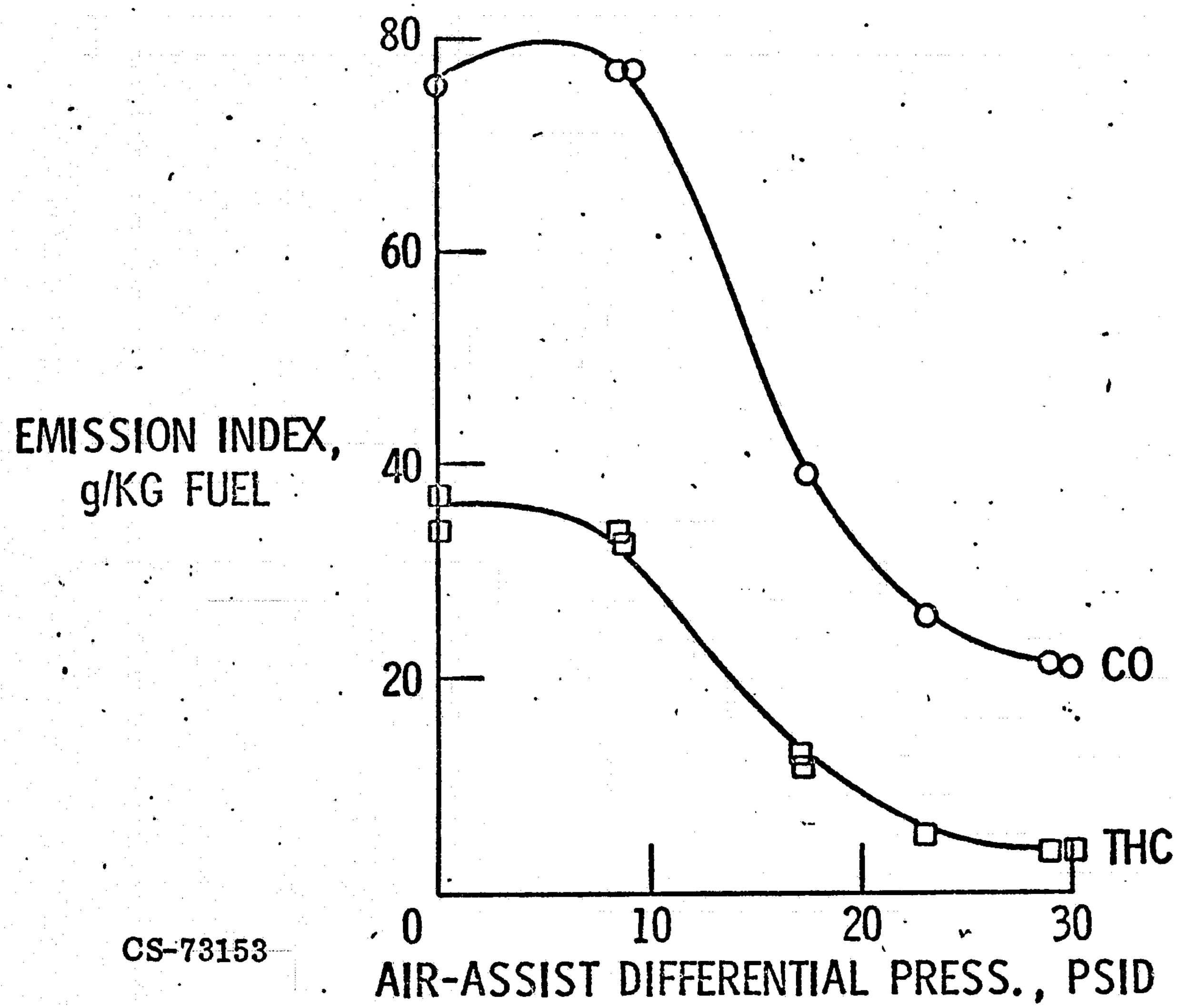
CONTRACT

- TRANSPIRATION COOLED LINERS (DDA)

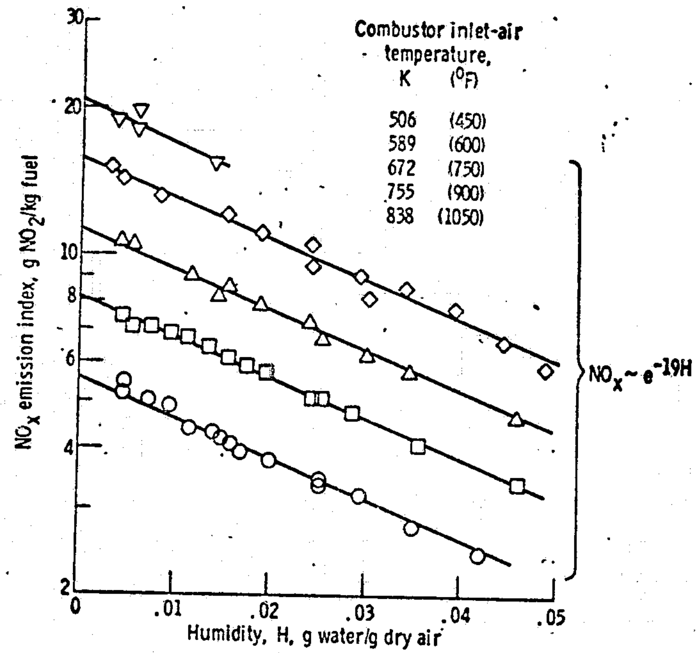
MAJOR CONTRIBUTIONS, 72 - 77

- DEMONSTRATED EFFICIENT COMBUSTION AT 4000°F EXIT TEMPERATURES
- DEMONSTRATED IDLE EMISSION REDUCTION WITH AIR-ASSIST FUEL INJECTION
- DEMONSTRATED NO_X EMISSION REDUCTION WITH AIR-BLAST FUEL INJECTION
- DEVELOPED CORRELATION OF NO_X EMISSIONS TO AMBIENT HUMIDITY
- DEVELOPED CORRELATION OF DILUTION JET MIXING PARAMETERS
- DEVELOPED CORRELATION OF FILM-COOLING PARAMETERS
- DEMONSTRATED THE EFFICIENCY OF SWIRL-FLOW FOR REDUCED LENGTH AFTERBURNERS

EFFECT OF IMPROVING FUEL ATOMIZATION



CS-73153



Effect of inlet-air humidity on formation of oxides of nitrogen. Combustor pressure, 6 atmospheres; reference Mach number, 0.065; nominal exit temperature, 1478 K (2200° F).

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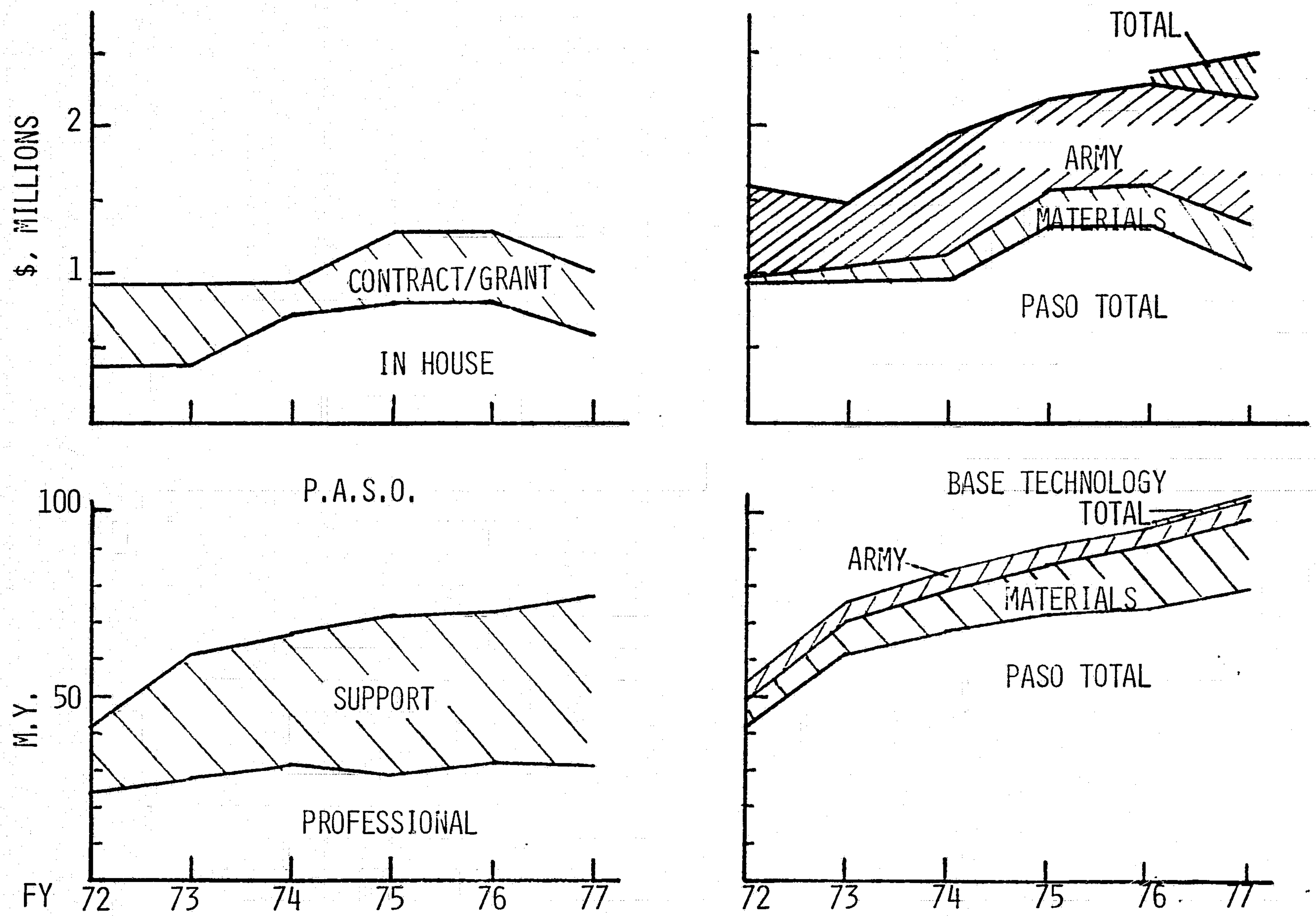
PROPULSION COMPONENTS

POWER TRANSFER RESEARCH

MECHANICAL COMPONENTS BRANCH
WILLIAM J. ANDERSON, CHIEF

POWER TRANSFER RESEARCH
R&T BASE MANPOWER AND RESOURCES



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MECHANICAL COMPONENTS BRANCH

OPERATIONS

ANALYSIS

SHAFT & ROTOR DYNAMICS SECTION

BALANCING
CRITICAL SPEEDS
RESPONSE
STABILITY
DAMPERS
GAS BEARINGS

BEARING, GEARING & TRANSMISSION SECTION

CONTACT FATIGUE
  BEARINGS
  GEARS
ROLLING BEARING
  DESIGN
  LUBRICATION
GEAR DESIGN
  LUBRICATION
TRANSMISSIONS

SEALS SECTION

GAS PATH SEALS
SHAFT SEALS
ROD SEALS
SEAL DYNAMICS
RUB ENERGETICS
FRETTING

LUBRICANTS SECTION

LIQUID LUBRICANTS
SOLID LUBRICANTS
EHD

LUBRICATION FUNDAMENTALS SECTION

FRICTION
WEAR
ADHESION
ION PLATING
  & SPUTTERING
HARD FACED
  COATINGS

MECHANICAL COMPONENTS BRANCH

MAJOR FACILITIES

SURFACE EXAMINATION TOOLS

- X-RAY DIFFRACTION
- SCANNING ELECTRON MICROSCOPY (SEM)
- AUGER ELECTRON SPECTROSCOPY (AES)
- FIELD ION MICROSCOPY (FIM)
- ELECTRON SPECTROSCOPY FOR CHEMICAL ANALYSIS (ESCA)

PLASMA SPRAY, ION AND SPUTTER COATING APPARATUS
4 MILLION DN ROLLING BEARING TEST RIG
MATERIAL FATIGUE TESTERS (CONTACT AND BENDING)
SPUR AND BEVEL GEAR TESTERS
SHAFT SEAL TESTER
HIGH TEMPERATURE RUB ENERGETICS RIG
ROTOR DYNAMICS TEST RIG
FIXED RATIO TRANSMISSION TEST STAND
VARIABLE SPEED RATIO TRANSMISSION TEST STAND
HYBRID HELICOPTER TRANSMISSION TEST STAND
OPTICAL ELASTOHYDRODYNAMICS TEST RIG
FERROGRAPHIC LUBRICANT ANALYSIS RIG

POWER TRANSFER RESEARCH

DESCRIPTION: A BROAD RANGE OF AREAS IS EXPLORED ANALYTICALLY AND EXPERIMENTALLY. THESE AREAS INCLUDE LUBRICATION THEORY, GEAR LIFE PREDICTIONS, SHAFT VIBRATIONS, BEARING AND SEALS LIFE EXTENSION AND PERFORMANCE IMPROVEMENT AT HIGH TEMPERATURES AND SHAFT SPEEDS, AND ADVANCED POWER TRANSMISSION RESEARCH.

TARGETS:

- DETERMINE FUNDAMENTALS OF WEAR AND ABRADABILITY OF COMPRESSOR GAS PATH SEALS AND DEVISE GAS PATH SEAL CLEARANCE CONTROL CONCEPTS USING ACTIVE AND/OR PASSIVE TECHNIQUES AND STRUCTURAL ANALYSIS TO ESTABLISH IMPROVED CONCEPTS THAT PROVIDE IMPROVED CONTROL OF CASE/ROTOR DISPLACEMENT - FY 1979

- DEMONSTRATE THE TECHNOLOGY FOR SAFELY OPERATING (BY MEANS OF IMPROVED BALANCING METHODS, DAMPER DESIGN, AND ROTOR DYNAMICS COMPUTER PROGRAMS) MULTI-MASS TURBINE ENGINE ROTORS AND POWER TRANSMISSION SHAFTING FOR HELICOPTERS AND STOL TYPE AIRCRAFT ABOVE THE FOURTH FLEXIBLE CRITICAL SPEED - FY 1979

- DETERMINE RUB THERMAL RESPONSE OF TURBINE GAS PATH SEALS AND ESTABLISH WEAR AND EROSION FUNDAMENTALS OF CERAMIC SHROUD MATERIALS - FY 1979

- DEMONSTRATE AND DEVELOP THE TECHNOLOGY FOR INCREASING THE LIFE (BY 200%) AND LOAD CARRYING CAPACITY (BY 50%) OF GEARS THROUGH IMPROVEMENTS IN TOOTH DESIGNS AND MANUFACTURING PROCESSES TO INCREASE THE TIME BETWEEN OVERHAUL OR REDUCE THE WEIGHT OF TRANSMISSION - FY 1980

POWER TRANSFER RESEARCH

KEY R&T PROGRAMS

PROGRAM	NEED	KEY PERSONNEL
IMPROVED GAS PATH SEALS	ENERGY EFFICIENT ENGINES OF THE 1980's (ENERGY CONSERVATION, INTERNATIONAL COMPETITION)	L. LUDWIG J. ZUK R. BILL
2.7 TO 3.0 MILLION DN BALL & ROLLER BEARINGS	ADVANCED TURBINE ENGINES OF THE 1980's; ADVANCED MILITARY ENGINES (MILITARY SUPERIORITY)	E. ZARETSKY B. HAMROCK R. PARKER
LOWER WEIGHT POWER TRANSFER AND TRANSMISSION SYSTEMS	MORE EFFICIENT ROTOR CRAFT AND POWERED LIFT (MILITARY SUPERIORITY AND INTERNATIONAL COMPETITION)	D. TOWNSEND S. LOEWENTHAL D. FLEMING
IMPROVED ENGINE SYSTEMS DYNAMICS	ADVANCED TURBINE ENGINES OF THE 1980's	L. LUDWIG D. FLEMING J. ZUK

POWER TRANSFER RESEARCH

CONTRIBUTIONS	APPLICATIONS & IMPACT
1. ADVANCED BALL BEARING DEVELOPMENT 100 FOLD LIFE IMPROVEMENT - 3 MILLION DN OPERATIONAL CAPABILITY	MAINSHAFT AND ACCESSORY BEARINGS IN PRATT & WHITNEY & GENERAL ELECTRIC AIRCRAFT GAS TURBINE ENGINES. INCORPORATED INTO BOTH COMPANIES BEARING PURCHASE SPECIFICATIONS.
2. BEARING RESTORATION BEARINGS WITH LIFE EXPECTANCY OF NEW BEARINGS AT HALF THE COST	MILITARY EQUIPMENT REPLACEMENT BEARINGS. SAVINGS: TO ARMY $1M/YR AIR FORCE $300K/YR
3. OH-58 HELICOPTER TAIL ROTOR DRIVE IMPROVED GREASE, SEALS AND BEARING MOUNTS PLUS DUST SHIELD	ENTIRE MILITARY FLEET BEING REFITTED. SAVINGS TO ARMY $900K/YR
4. HYDRODYNAMIC SEAL NASA LIFTOFF PRINCIPLE EMPLOYED.	SHUTTLE LOX TURBOPUMP. SOLVED THE SEAL LIFE PROBLEM
5. TRANSMISSION SEAL IMPROVED SHAFT RIDING OIL SEAL	BILL OF MATERIAL IN BELL 214B. BEING FLIGHT TESTED IN BELL 214A, UH-1 AND COBRA HELICOPTERS

CONTRIBUTIONS	APPLICATIONS & IMPACT
6. <u>MAINSHAFT SEALS</u> NASA GAS LUBRICATED SELF-ACTING SEAL	INDUSTRIAL GAS COMPRESSORS (INGERSOLL RAND) ATEGG ENGINE SEAL - KOPPERS STEAM SEAL - WESTINGHOUSE COMPUTER PROGRAMS - SEALOL CO. ADVANCED AIRCRAFT TURBINE ENGINES
7. <u>ION PLATED & SPUTTERED DRY FILM LUBRICANT COATINGS</u>	HOSTS OF APPLICATIONS TURBINE ENGINE VANE PIVOTS SPACECRAFT PARTS (1000 ON VIKING)
8. <u>PLASMA SPRAYED SELF-LUBRICATING COATINGS WITH WIDE TEMPERATURE SPECTRUM CAPABILITIES</u> CRYOGENIC TO 1600°F TEMPERATURE RANGE	TURBINE ENGINE VANE PIVOTS TURBINE ENGINE HOT SECTION PIVOTS INDUSTRIAL MACHINERY (2 LICENSED VENDORS)
9. <u>COMPUTERIZED SHAFT BALANCING</u> FOR AUTOMATIC BALANCING OF HIGH SPEED FLEXIBLE SHAFTS	MORE EFFICIENT, LESS COSTLY ROTOR BALANCING. ENGINE DEMONSTRATOR PROGRAMS BEING CONDUCTED ON THE T55, T53 AND T700 ENGINES.
10. <u>MIST LUBRICATION OF HIGH SPEED BALL BEARINGS</u> CAPABILITY DEVELOPED FOR 2 MILLION DN BEARING OPERATION. REDUCES POWER LOSS. SIMPLIFIES MECHANICAL DESIGN.	EMERGENCY BACK-UP SYSTEMS ON TURBINE ENGINES AND TRANSMISSIONS. EMERGENCY SYSTEM ON THE T700 ENGINE.

CONTRIBUTIONS

11. Low-Cost High Stability Fixed Geometry Journal Bearings

    Lower cost anti-whirl bearings. Mass produced by broaching.

12. Computer Program for Sector Shaped Thrust Bearing Pad

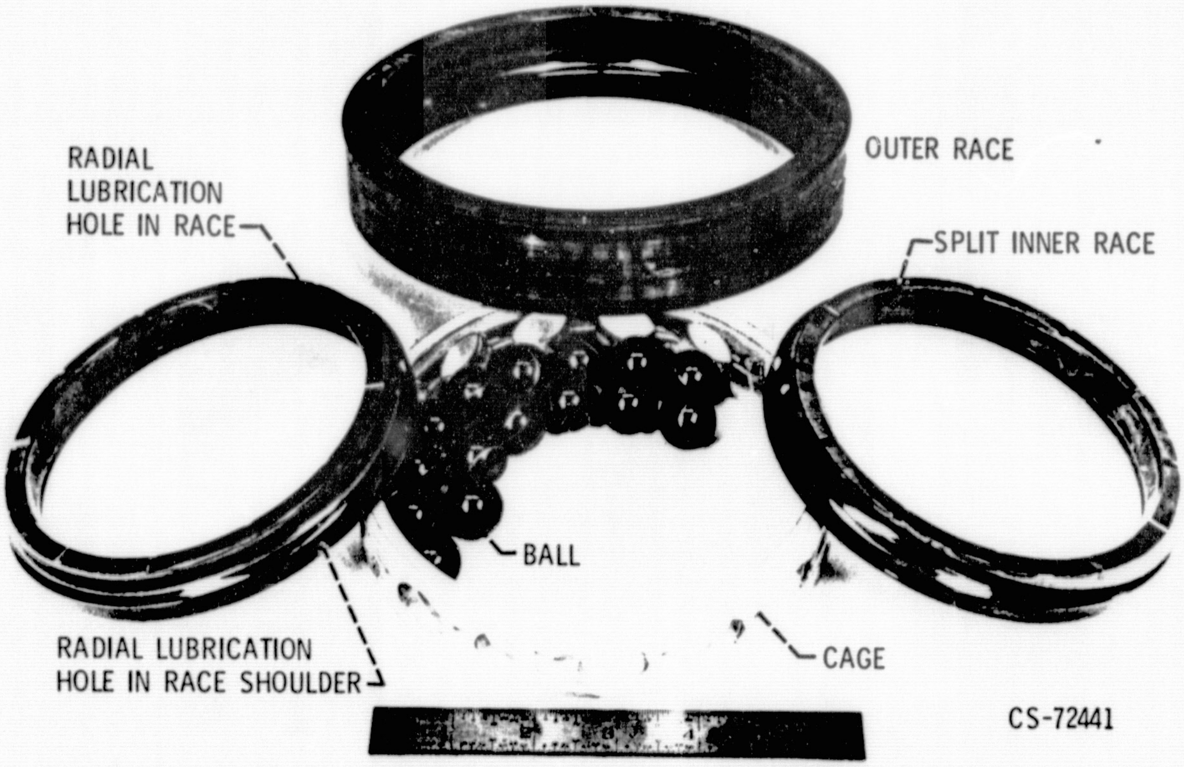
    First exact solution for sector shaped pad. Applies to liquids and gases.

APPLICATIONS & IMPACT

Used in ground based gas turbine engine (T-55, Avco-Lycoming). Potential applications in superchargers and small turbomachinery.

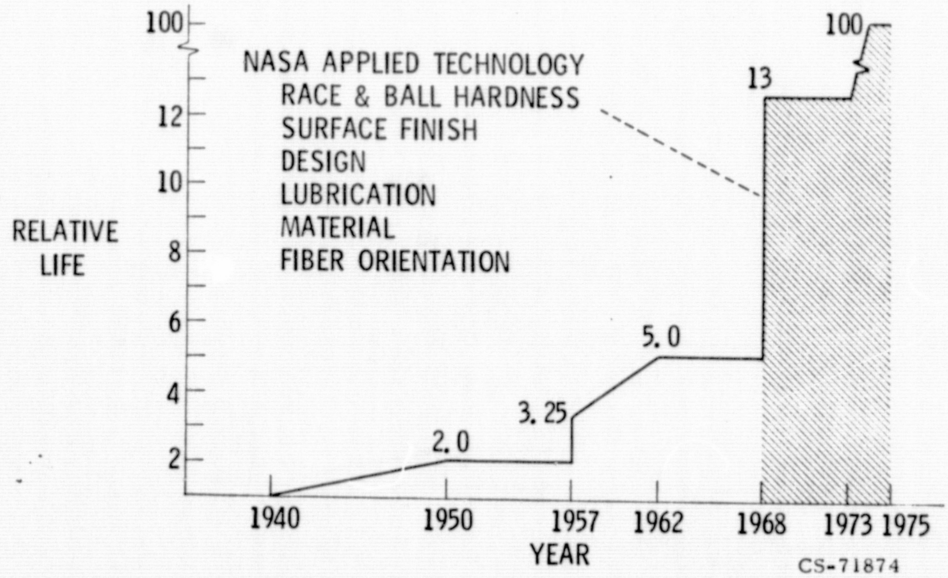
Upgrades design capability for liquid and gas lubricated thrust bearings. Widespread use in industrial machinery.

UNFAILED 120-mm BORE ANGULAR-CONTACT HIGH-SPEED TEST BALL BEARING



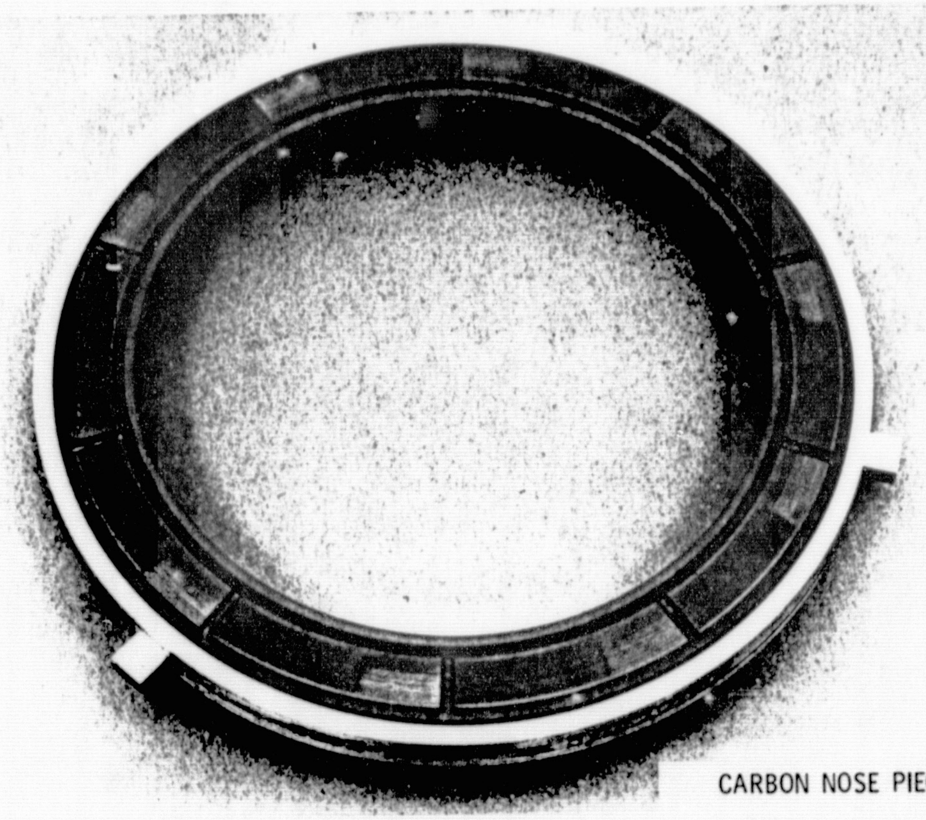
CS-72441

STATE-OF-THE-ART ROLLING-ELEMENT BEARING HISTORY

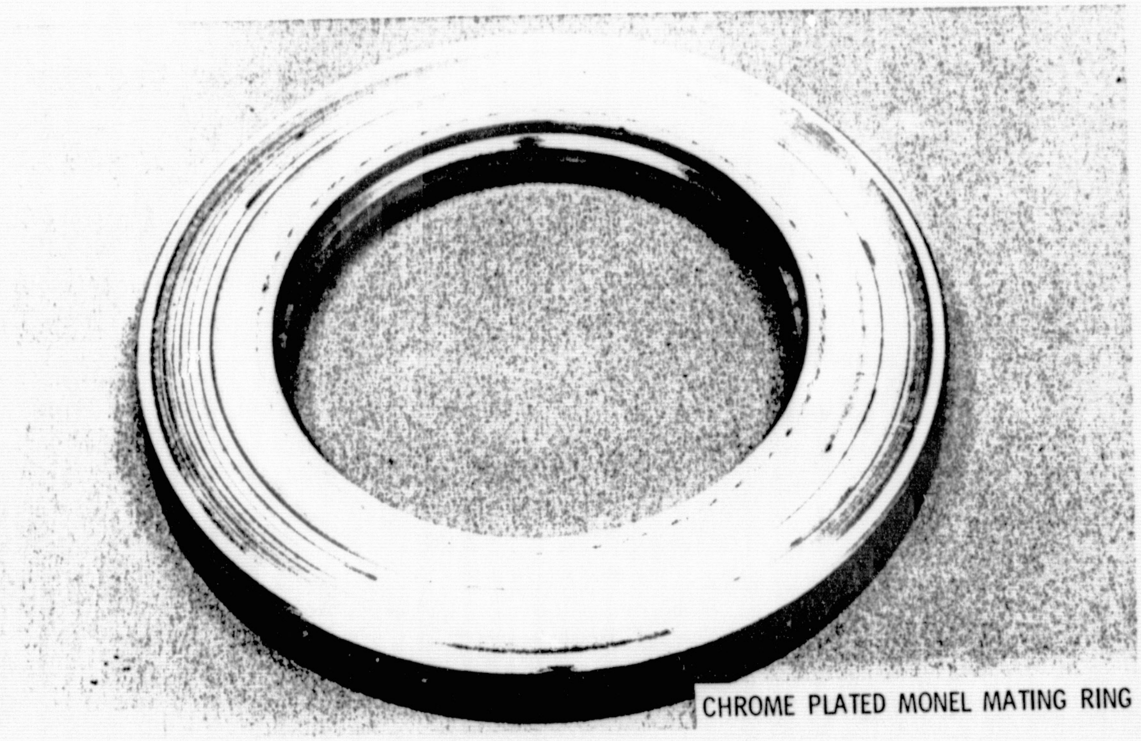


CS-71874

HYDRODYNAMIC SEAL AFTER 12 hr (100 STARTS)
OPERATION IN LIQUID OXYGEN AT 400 psia ΔP, 32 000 rpm

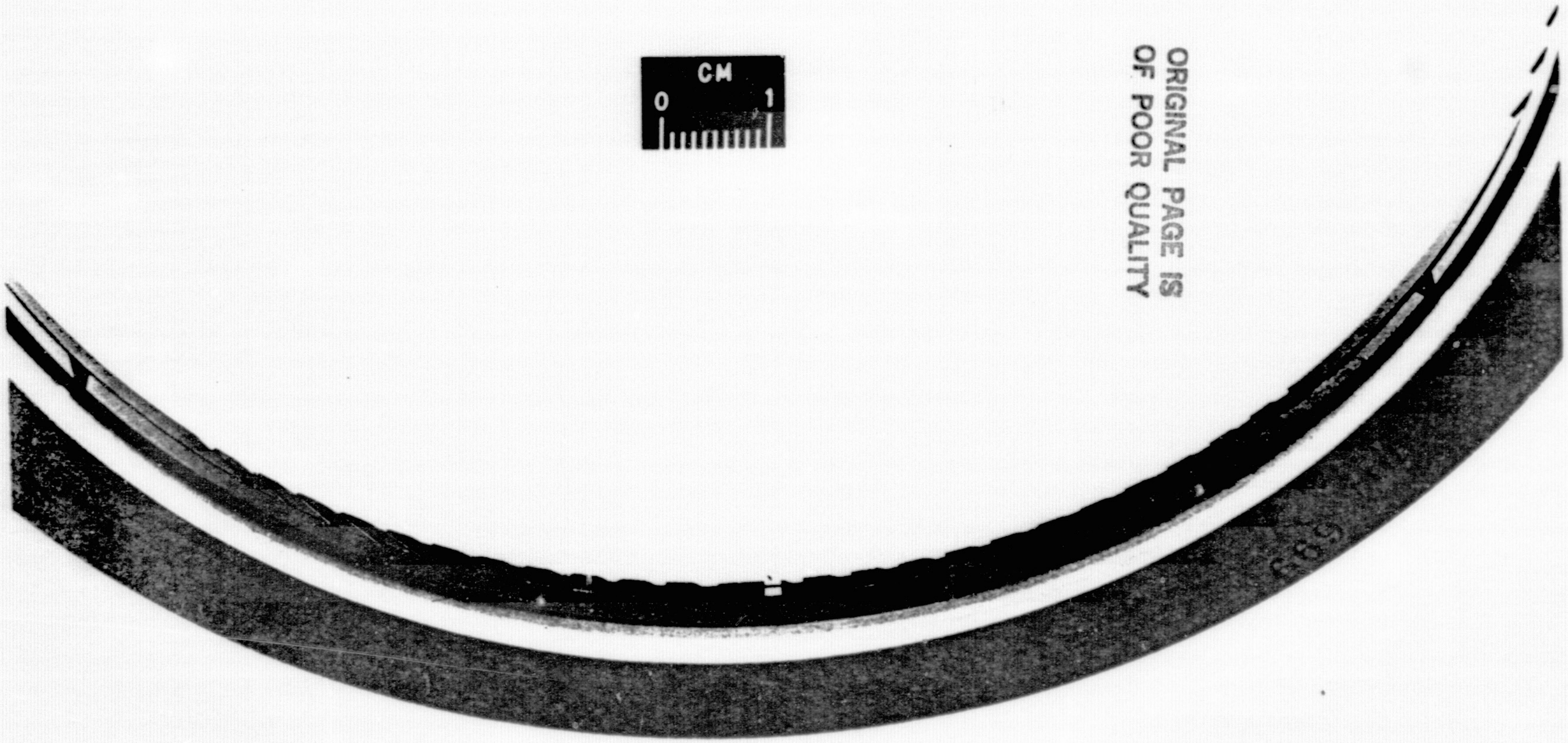


CARBON NOSE PIECE

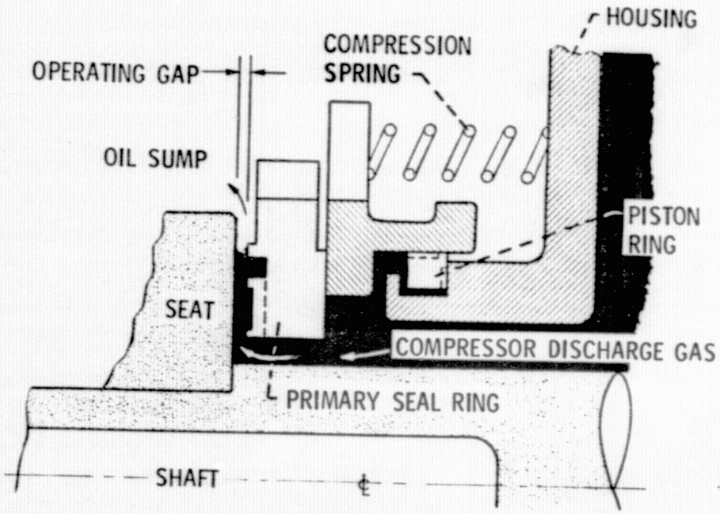


CHROME PLATED MONEL MATING RING

TRANSMISSION SEAL AFTER 1200-hr OPERATION IN BELL 214B HELICOPTER



SELF-ACTING FACE SEAL SHOWING SHROUDED RAYLEIGH STEP-PAD DESIGN



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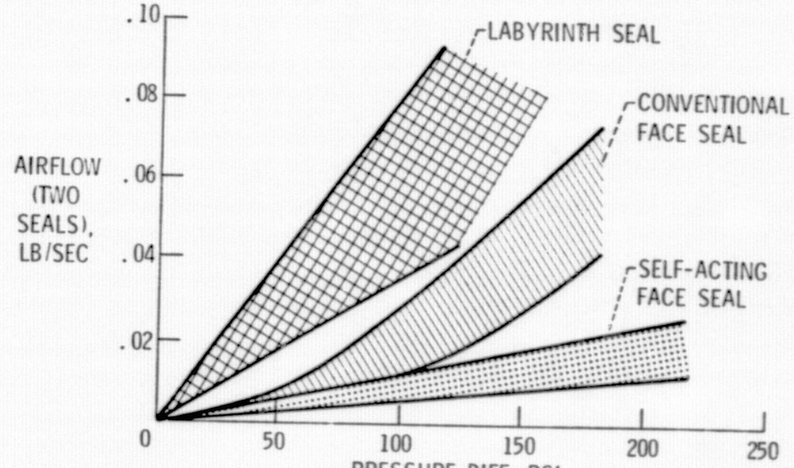
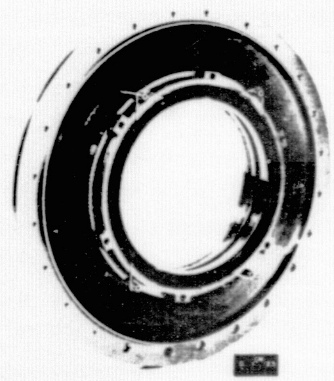
MAIN SHAFT SEAL PERFORMANCE IN SMALL GAS TURBINE ENGINE



CS-72335

SELF-ACTING MAINSHAFT SEAL



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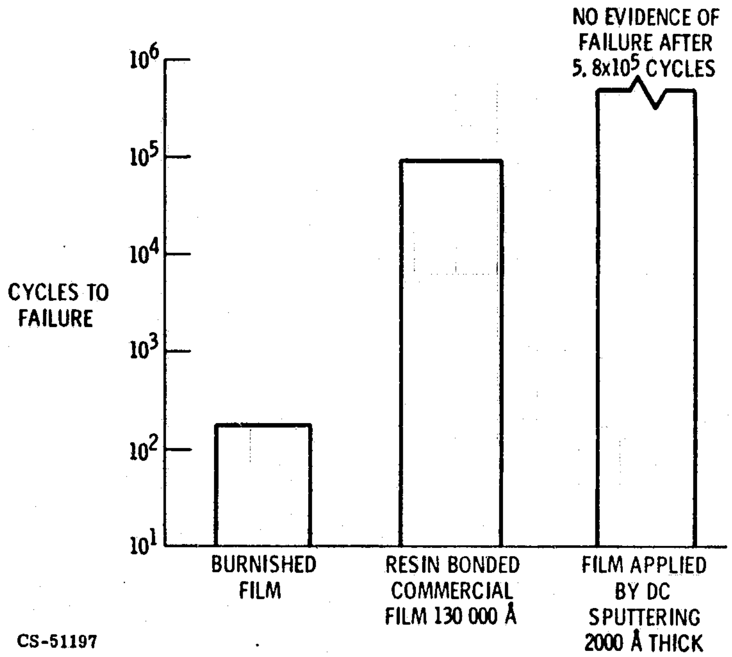
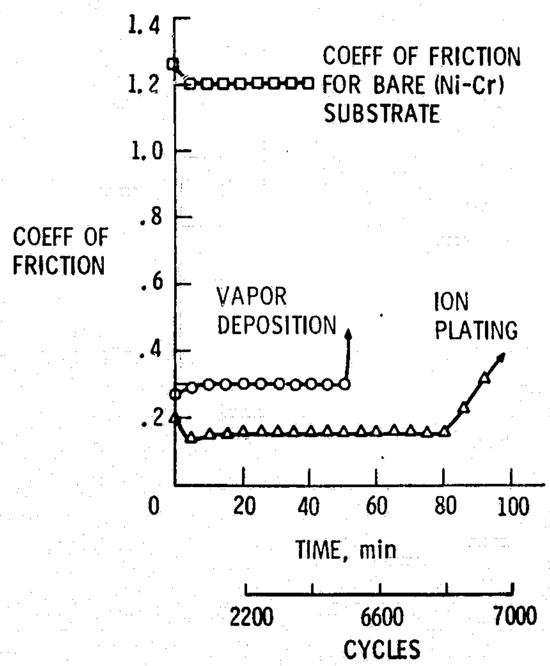
ENDURANCE LIVES OF MoS_2 FILMS APPLIED BY VARIOUS TECHNIQUES



CS-51197

COEFF OF FRICTION OF NIOBIUM SLIDING ON (Ni-Cr) ALLOY WITH GOLD DEPOSITED BY VAPOR DEPOSITION, AND ION PLATING ABOUT 2000 Å THICK (LOAD, 250 g; SPEED, 5 ft/min; AMBIENT TEMP, 10^{-11} TORR)



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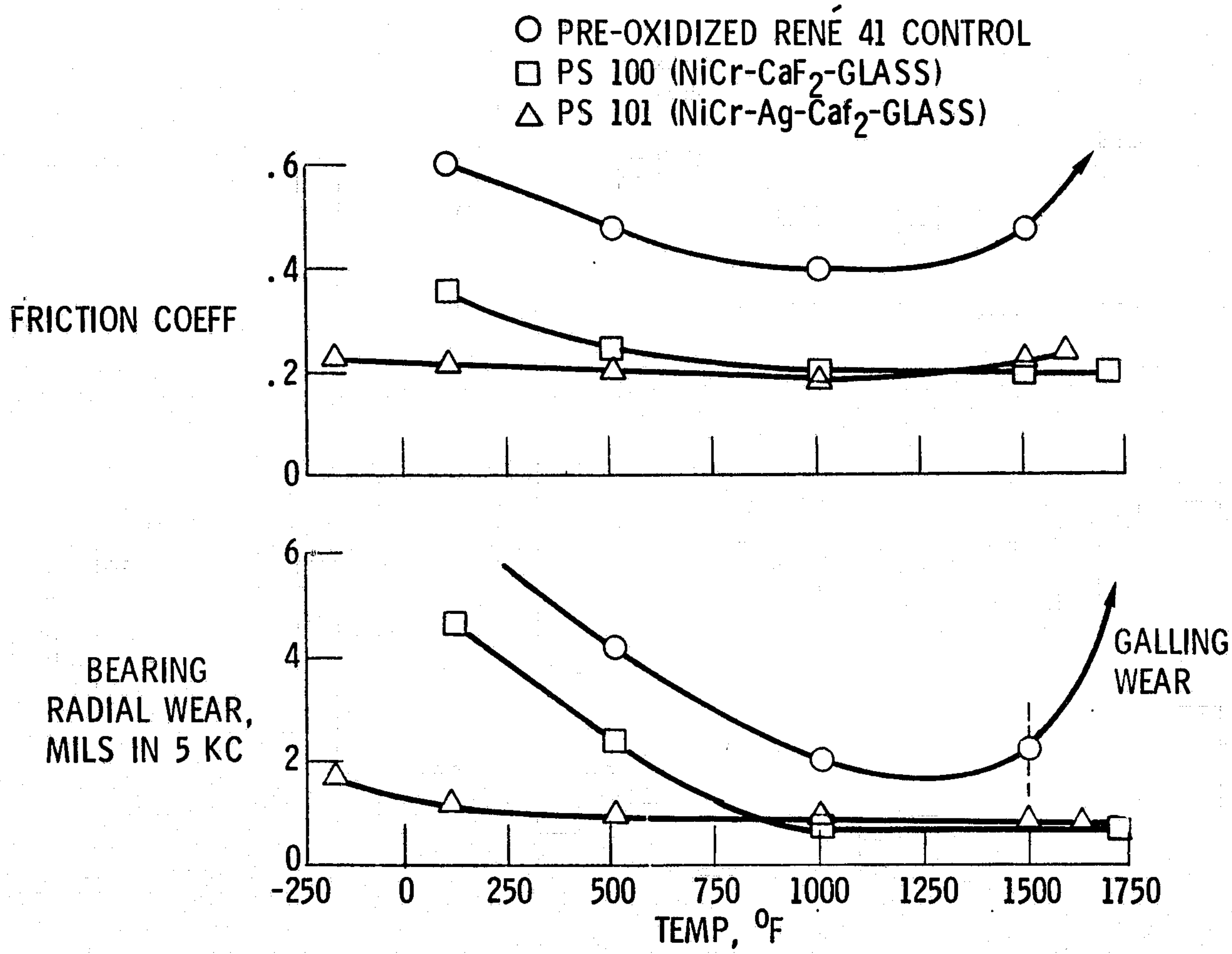
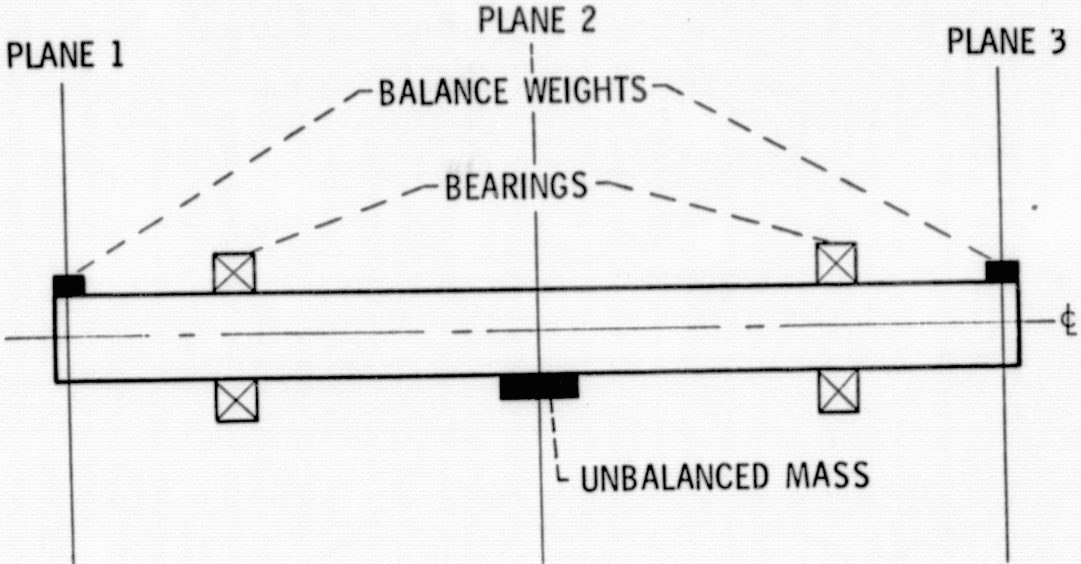
PLASMA-SPRAYED COATINGS FOR SELF-ALINING BEARINGS



TWO-PLANE BALANCE WITH RIGID ROTOR



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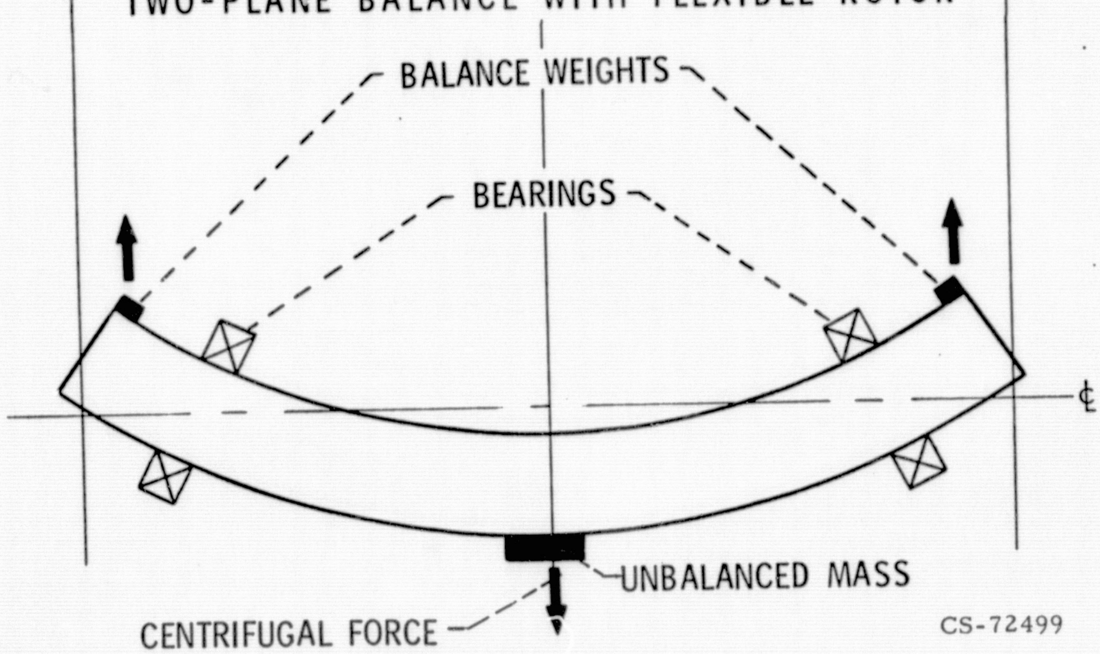
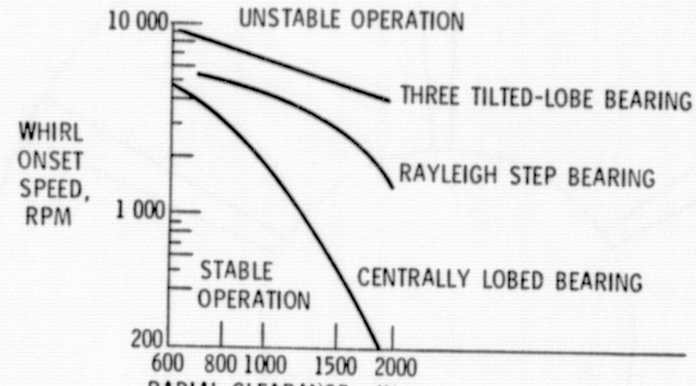
TWO-PLANE BALANCE WITH FLEXIBLE ROTOR



CS-72499

LOW-SPEED BALANCING TECHNIQUE FOR RIGID ROTORS (WITH UNBALANCED MASS IN PLANE 2 AND BALANCE WEIGHTS IN PLANES 1 AND 3) IS NOT ADEQUATE FOR BALANCING HIGH SPEED FLEXIBLE ROTORS. IN FACT, AT THE CRITICAL SPEED THIS BALANCING METHOD IS DETRIMENTAL SINCE SHAFT BENDING IS INCREASED BY THE BALANCE WEIGHTS.

STABILITY OF FIXED GEOMETRY BEARINGS



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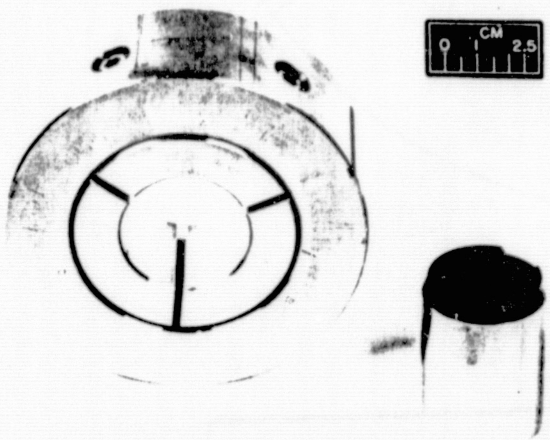
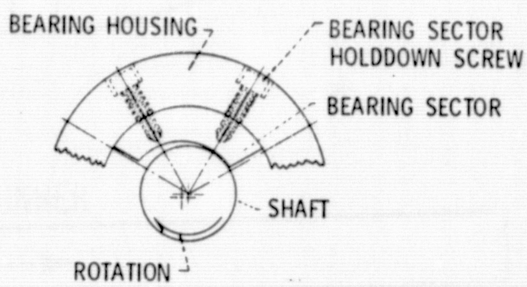
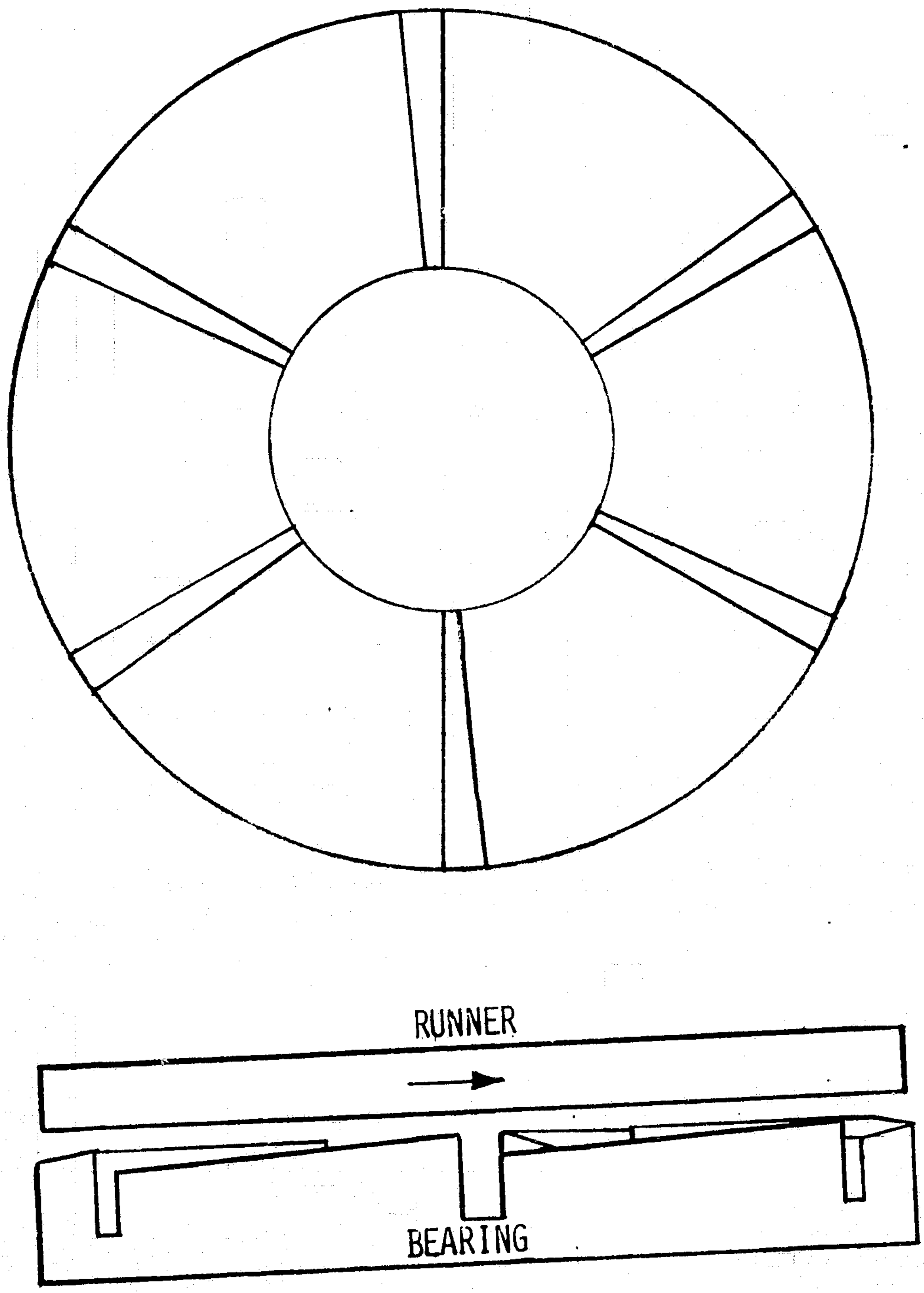
THREE-TILTED-LOBE BEARING



ASSEMBLED BEARING CONFIGURATION



BEARING SECTOR ASSEMBLY



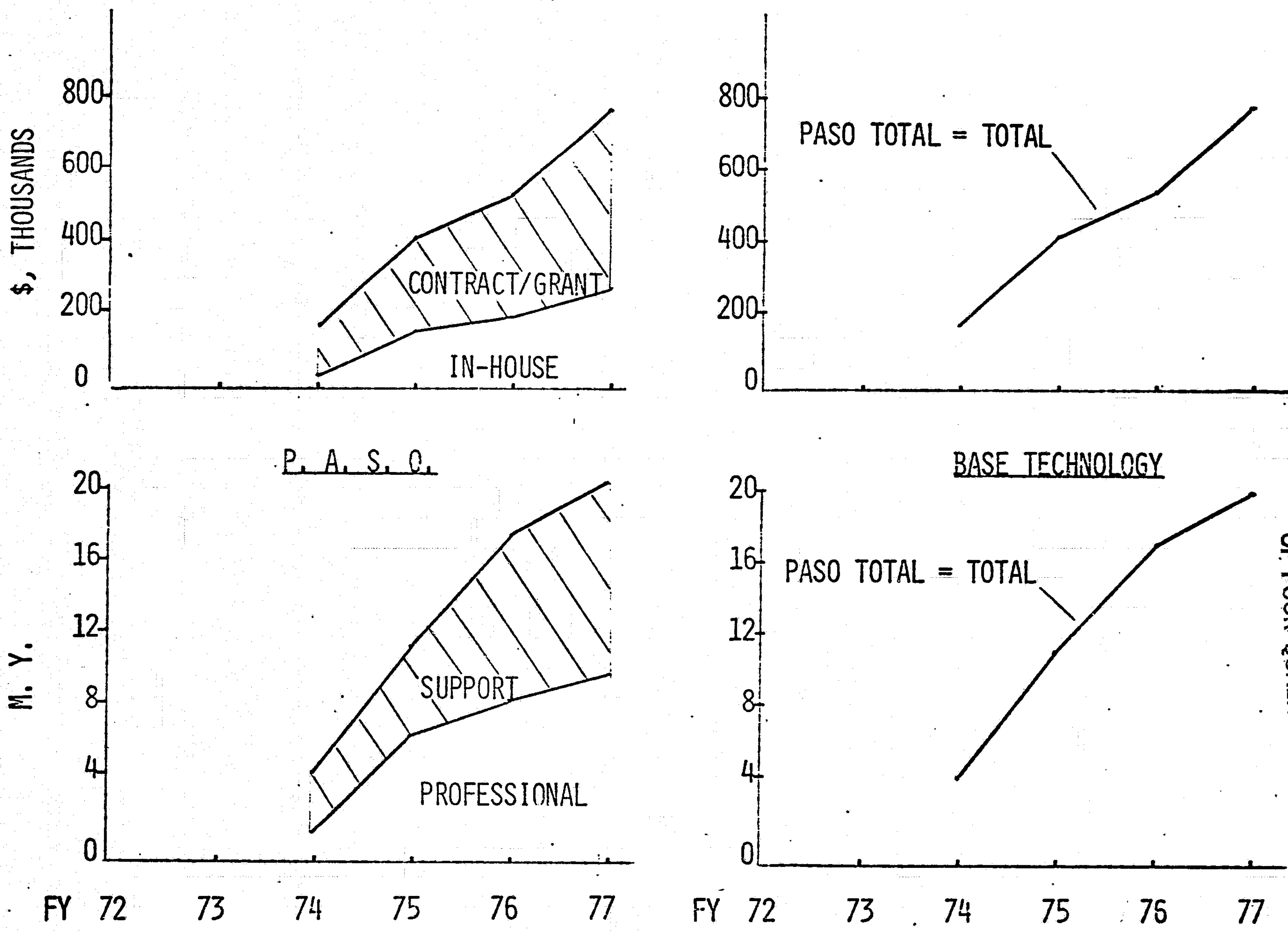
SECTOR PAD THRUST BEARING

PROPULSION COMPONENTS

FUELS TECHNOLOGY

JACK S. GROBMAN - AIRBREATHING ENGINES DIVISION

PROPULSION FUEL RESEARCH



COMBUSTION & POLLUTION RESEARCH BRANCH
DON PETRASH, CHIEF

- EXPERIMENTAL COMBUSTOR SECTION
  ROBERT JONES, HEAD
- ADVANCED TECHNOLOGY SECTION
  JACK GROBMAN, HEAD
  - *ALBERT ANTOINE
  - *HELMUT BUTZE
  - JAMES FEAR
  - *ROBERT FRIEDMAN
  - CARL NORGREN
  - *THAINE REYNOLDS
  - STEVE RIDDLEBAUGH
  - *ARTHUR SMITH
- EMISSIONS TECHNOLOGY SECTION
  LARRY DIEHL, HEAD
- ENVIRONMENTAL IMPACT SECTION
  E. LEZBERG, HEAD

*FUELS TECHNOLOGY PROGRAM

RESEARCH FACILITIES

COMBUSTOR RESEARCH - ALTERNATIVE FUELS

- CE-5B, ENGINE RESEARCH BUILDING
  - MAX. PRESSURE, 450 PSIA
  - MAX. INLET TEMPERATURE, 900° F (1200° F)
  - MAX. AIRFLOW, 35 LB/SEC

FUELS SYNTHESIS AND CHARACTERIZATION

- ANALYTICAL LABORATORY
- DISTILLATION LABORATORY
  - ATMOSPHERIC AND VACUUM
  - MAX. CAPACITY, 18 GAL.
- HYDROPROCESSING LABORATORY
  - FLOW RATE, 1 LITER/HOUR
  - MAX. PRESSURE, 3000 PSI
  - MAX. TEMPERATURE, 1000° F

FUELS TECHNOLOGY

OBJECTIVE: EVALUATE THE POTENTIAL CHARACTERISTICS OF FUTURE JET AIRCRAFT FUELS, DETERMINE EFFECTS ON ENGINE COMPONENTS AND EVOLVE COMPONENT TECHNOLOGY

TARGETS:

- o IDENTIFY PROBABLE PROPERTIES OF FUTURE ALTERNATIVE AVIATION TURBINE FUELS REFINED FROM EITHER PETROLEUM, SHALE OIL OR COAL SYNCRUDES - FY 1978

- o DETERMINE EFFECTS OF RELAXING FUEL SPECIFICATIONS ON COMBUSTOR PERFORMANCE, EMISSIONS, AND DURABILITY: AND EVOLVE COMBUSTOR TECHNOLOGY FOR BROAD SPEC. FUELS - FY 1978

- o DETERMINE THE EFFECTS OF RELAXING FUEL SPECIFICATIONS ON FUEL SYSTEM PERFORMANCE AND DURABILITY AND ON ENGINE MATERIALS SUCH AS FUEL SYSTEM ELASTOMERS AND HOT SECTION ALLOYS AND COATINGS, AND TO EVOLVE AND EVALUATE TECHNOLOGY FOR BROAD SPEC. FUELS - FY 1978

- o PERFORM ENGINE DEMONSTRATION TESTS WITH CANDIDATE ALTERNATIVE FUELS - FY 1981

TARGET: TO IDENTIFY THE PROBABLE PROPERTIES OF FUTURE ALTERNATIVE AVIATION TURBINE FUELS REFINED FROM EITHER PETROLEUM, SHALE OIL OR COAL SYNCRUDES - FY 1978

PRINCIPLE PROGRAM ELEMENTS

IN-HOUSE

- LABORATORY SYNTHESIS OF JET FUELS FROM SHALE OIL AND COAL SYNCRUDES
- LABORATORY SYNFUEL CHARACTERIZATION STUDIES
  - COMBUSTION PROPERTIES, E. G. AROMATIC CONTENT
  - THERMAL STABILITY
  - FREEZING POINT

CONTRACT/GRANT

- STUDY GRANT, "FORECAST OF FUTURE AVIATION FUELS", U. C. L. A.
- REFINERY ENERGY OPTIMIZATION STUDY, GORDIAN ASSOC.
- LABORATORY SYNFUEL PROCESSING STUDIES
  - EXXON
  - ATLANTIC RICHFIELD
- STUDY GRANT, "STABILITY OF NITROGEN - CONTAINING TURBINE FUELS", COLORADO SCHOOL OF MINES

TARGET: TO DETERMINE THE EFFECTS OF RELAXING FUEL SPECIFICATIONS ON COMBUSTOR PERFORMANCE, EMISSIONS, AND DURABILITY: AND TO EVOLVE AND EVALUATE COMBUSTOR TECHNOLOGY FOR BROAD. SPEC. FUELS - FY 1978

PRINCIPLE PROGRAM ELEMENTS

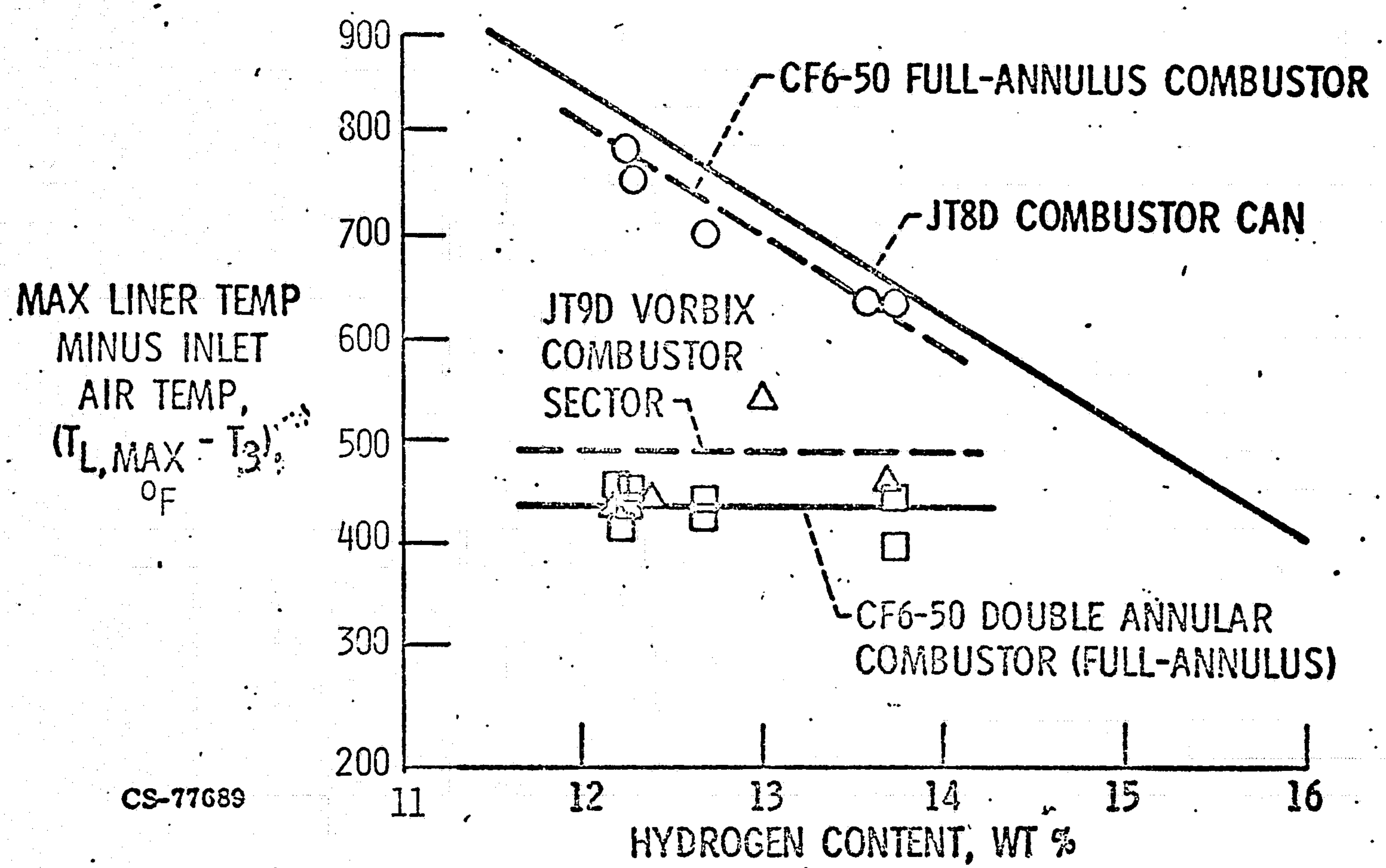
IN-HOUSE

- EXPERIMENTAL EVALUATION OF CONVENTIONAL COMBUSTOR WITH BROAD SPEC. FUELS
- EVOLUTION AND EVALUATION OF CONCEPTUAL COMBUSTORS FOR BROAD SPEC. FUELS
- EXPERIMENTAL MEASUREMENT OF FLAME RADIATION FOR VARYING FUEL PROPERTIES

CONTRACT/GRANT

- EXPERIMENTAL EVALUATION OF LOW-POLLUTANT COMBUSTORS WITH BROAD-SPEC. FUELS: GE, P&W
- COMBUSTOR DESIGN STUDY - BROAD SPEC. FUELS
- STUDY OF EFFECT OF FUEL PROPERTIES ON SOOT FORMATION AND OXIDATION, M.I.T.
- EVOLUTION AND EVALUATION OF COMBUSTOR TECHNOLOGY FOR BROAD SPEC. FUELS

EFFECT OF HYDROGEN CONTENT OF FUEL ON COMBUSTOR LINER SURFACE TEMPERATURE



CS-77689

TARGET: TO DETERMINE THE EFFECTS OF RELAXING FUEL SPECIFICATION ON FUEL SYSTEM PERFORMANCE AND DURABILITY AND ON ENGINE MATERIALS SUCH AS FUEL SYSTEM ELASTOMERS AND HOT SECTION ALLOYS AND COATINGS, AND TO EVOLVE AND EVALUATE TECHNOLOGY FOR BROAD SPEC. FUELS - FY 1978

PRINCIPLE PROGRAM ELEMENTS

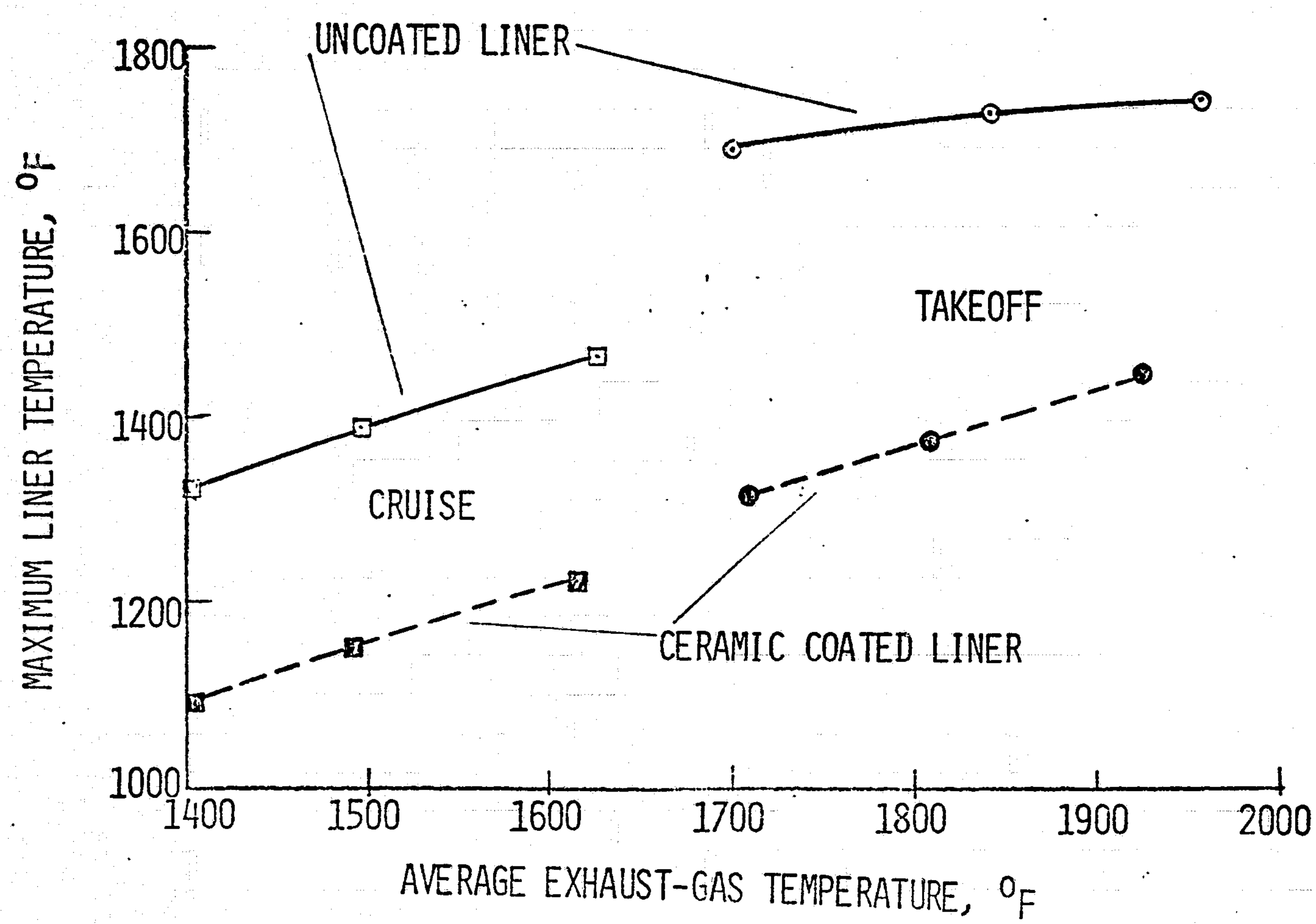
IN-HOUSE

- EVALUATION OF THERMAL BARRIER COATINGS FOR COMBUSTORS
- ACCELERATED HOT CORROSION-TURBINE MATERIAL TESTS WITH ALTERNATIVE FUELS

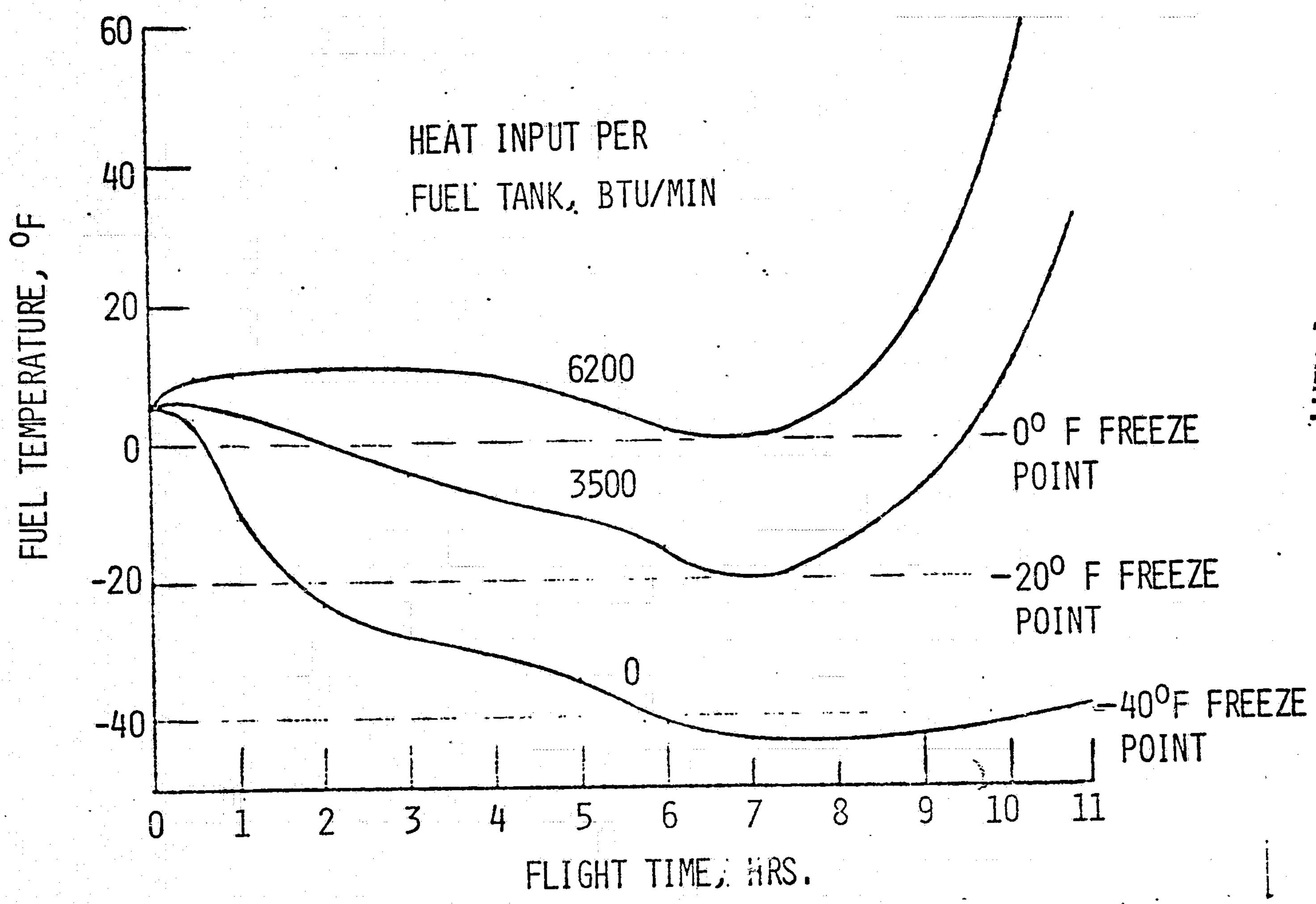
CONTRACT

- FUEL SYSTEM DESIGN STUDY FOR HIGH FREEZING POINT FUELS, BOEING
- EXPERIMENTAL STUDY OF PUMPABILITY IN LOW TEMPERATURE FUEL SYSTEMS
- EXPERIMENTAL EVALUATION OF EFFECT OF FUEL PROPERTIES ON ELASTOMERS, JPL

EFFECT OF CERAMIC COATING ON MAXIMUM LINER TEMPERATURE



FUEL TANK TEMPERATURES WITH CONSTANT HEAT INPUT - 5000 N.M.



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MAJOR CONTRIBUTIONS

- SYNTHESIZED JET AIRCRAFT SYNFUELS FROM SHALE OIL AND COAL SYNCRUDES
- CORRELATED THERMAL STABILITY OF SYNFUELS WITH CHEMICAL COMPOSITION
- EVALUATED EFFECTS OF VARYING FUELS PROPERTIES ON A CONVENTIONAL COMBUSTOR LINER AT SIMULATED OPERATING CONDITIONS
- EVALUATED EFFECTS OF VARYING FUEL PROPERTIES ON LOW-POLLUTANT COMBUSTORS AT SIMULATED OPERATING CONDITIONS
- EVALUATED THE EFFECT OF THERMAL BARRIER COATING CONSISTING OF YTTRIA STABILIZED ZIRCONIA CERAMIC ON A CONVENTIONAL COMBUSTOR LINER
- PERFORMED ANALYTICAL STUDY OF EFFECT OF HIGH FREEZING POINT FUELS ON THE DESIGN OF THE AIRCRAFT FUEL SYSTEM

PROPULSION COMPONENTS

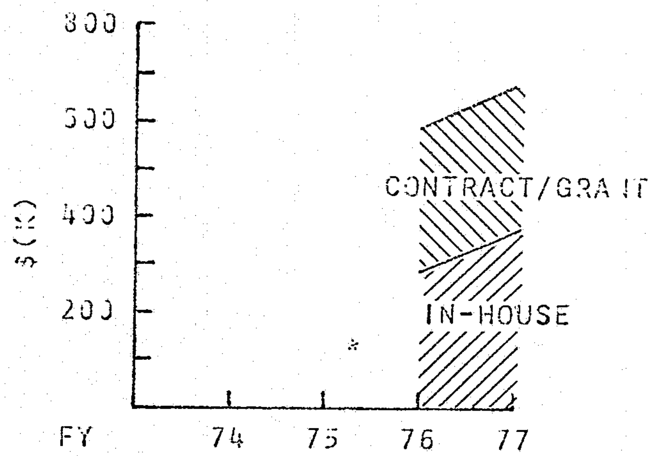
PROPULSION INSTRUMENTATION RESEARCH

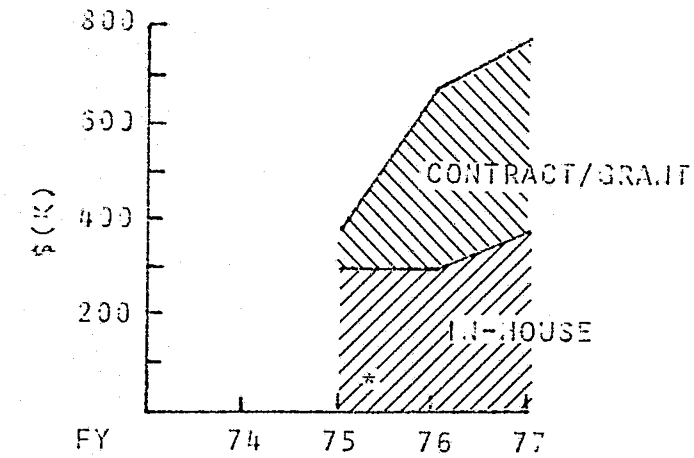
Norman C. Wenger

Airbreathing Engines Division

R & T TRENDS

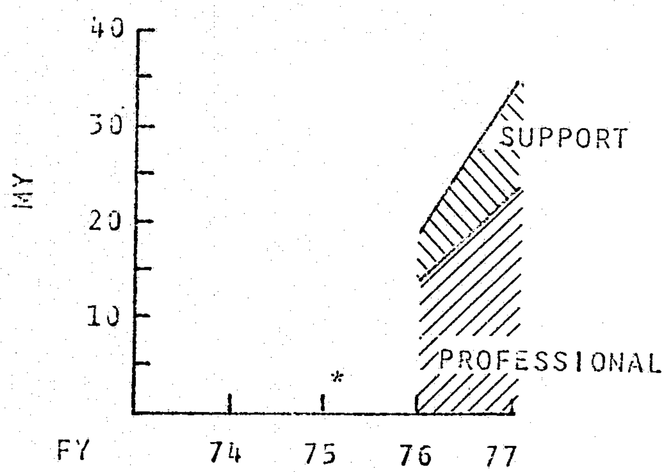
INSTRUMENTATION

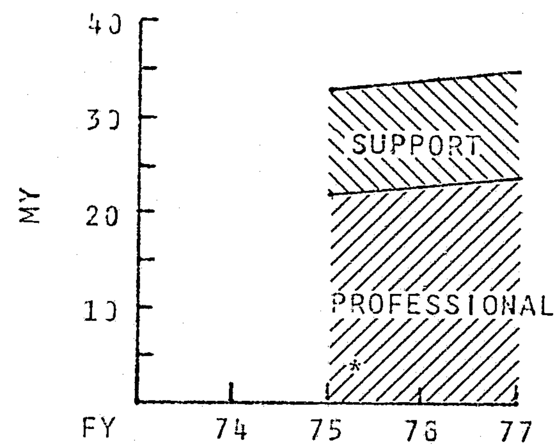




(ADJUSTED DATA THAT INCLUDES INSTRUMENTATION R&T BASE ACTIVITIES INCLUDED IN OTHER DISCIPLINE AREAS)

P.A.S.O.

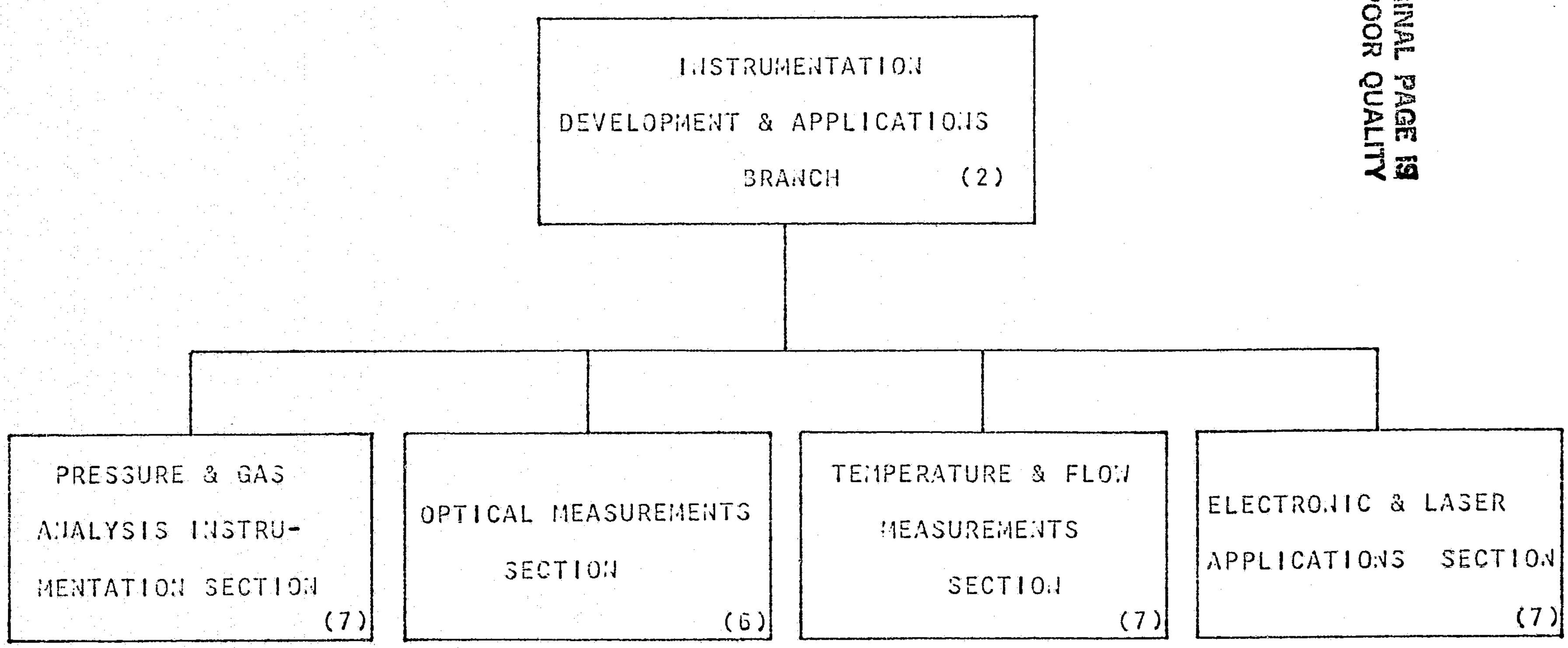




*INSTRUMENTATION DEVELOPMENT & APPLICATIONS BRANCH WAS FORMED IN AUGUST 1974.

LEWIS RESEARCH CENTER

INSTRUMENTATION ORGANIZATION CHART



INSTRUMENTATION MISSION

-- Expand and demonstrate the technology required for significantly improving present instrumentation and measurement techniques to a level commensurate with the needs of advanced systems and component research programs

TARGET AREAS*:

- o Turbine Blade Temperature Measurement
- o Gas Temperature Measurement
- o Gas Flow Measurement
- o Blade Tip Clearance Measurement
- o Blade Flutter Measurement
- o Rotary Instrumentation Systems

*Also target areas for NASA/USAF Joint Program on Engine Instrumentation

TURBINE BLADE TEMPERATURE MEASUREMENT

TARGET: Determine the feasibility of using surface film sensors and remote sensing infrared techniques for measuring surface temperature distributions on turbine blades at temperatures up to 2000^{o}F.

PROGRAM:

IN-HOUSE

- o Miniature thermocouples
- o Infrared techniques - multicolor pyrometry
- o Thin film thermocouples

CONTRACT/GRANT

- o Thin film thermocouple development (Pratt & Whitney Aircraft)

GAS TEMPERATURE MEASUREMENT

TARGET: Determine the feasibility of using both advanced probe designs and Raman spectroscopy for measuring combustion gas temperature up to $4000^{\circ}F$ at pressures up to 40 atmospheres.

PROGRAM:

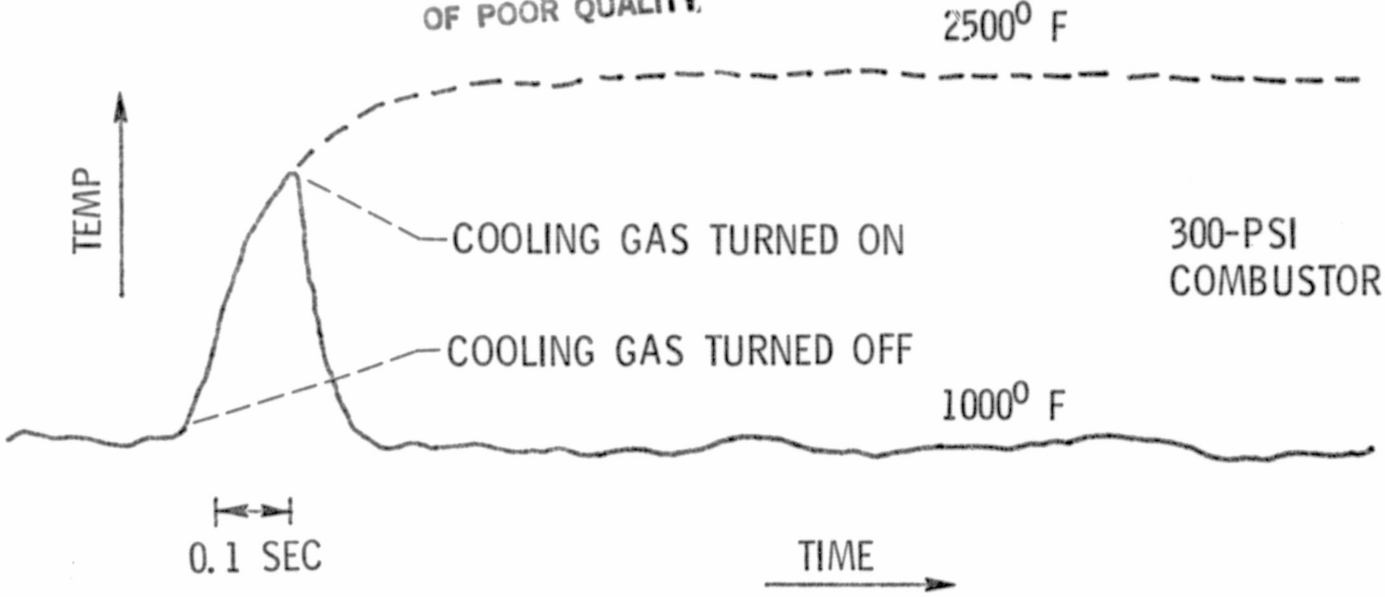
IN-HOUSE

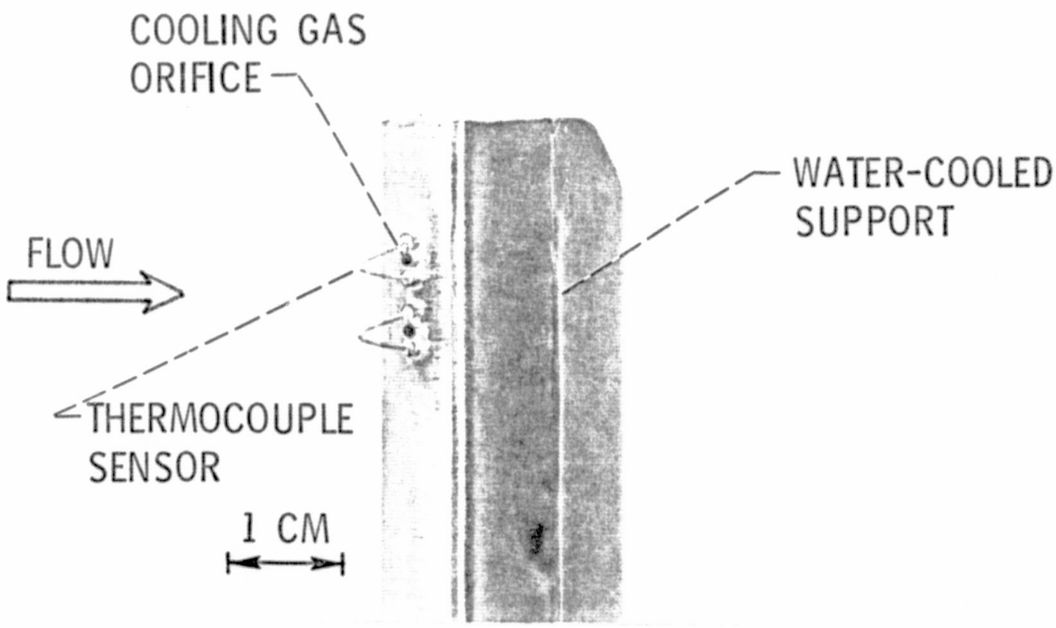
- Gas cooled thermocouple probe
- Raman spectroscopy

CONTRACT/GRANT

- Raman spectroscopy (Polytechnic Institute of New York)

GAS COOLED THERMOCOUPLE PROBE





PROBE HEAD

GAS FLOW MEASUREMENT

TARGET: Demonstrate techniques for accurately mapping gas flows in inlets and within the moving blade rows of compressor stages.

PROGRAM:

IN-HOUSE

- o Laser Doppler velocimeter
- o Holocamera
- o Drag force anemometer

CONTRACT/GRANT

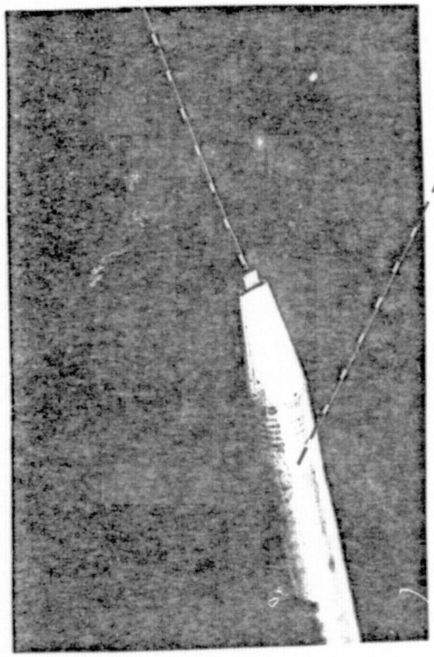
- o High temperature pressure transducer (Boeing Aerospace)

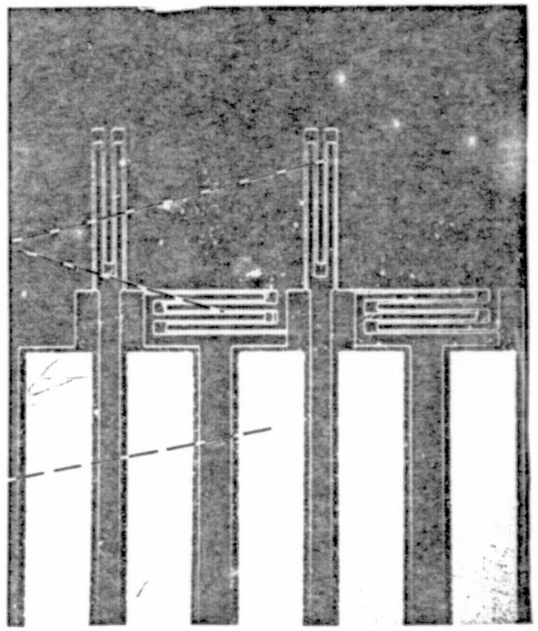
DRAG FORCE ANEMOMETER

(BEAM PROBE)

SILICON BEAM
1.5 mm WIDE

6.2 mm DIA.





BLADE TIP CLEARANCE MEASUREMENT

TARGET: Demonstrate techniques for measuring individual clearance between moving compressor or turbine blades and the outer casing.

PROGRAM:

IN-HOUSE

- Capacitance Probes

CONTRACT/GRANT

- Development of a laser optic tip clearance measurement system (Pratt & Whitney Aircraft)

BLADE FLUTTER MEASUREMENT

TARGET: Determine the feasibility of using blade mounted sensors and remote sensing techniques for determining the onset, modal patterns, frequencies, and amplitudes of aeroelastic blade instability.

PROGRAM:

<u>IN-HOUSE</u>

- Stroboscopic Imagery System
- Photoelectric Scanning System
- Strain gage signal monitor
- Strain gage system development

<u>CONTRACT/GRANT</u>

- Surface pressure measurement on compressor blades (Pratt & Whitney Aircraft)
- Strain gage system reliability test (Pratt & Whitney Aircraft)
- Thin film strain gage system development
- Investigation of coherent optical techniques for measuring blade flutter parameters (Auburn University)

ROTARY INSTRUMENT SYSTEM

TARGET: Demonstrate a rotary instrument system capable of transmitting up to 100 channels of data from a rotating shaft at shaft speeds up to 23,000 RPM.

PROGRAM: CONTRACT/GRANT

- Development of a modular system for thermocouple, dynamic strain, static strain, and pressures signals (Acurex Corp.)

INSTRUMENTATION CONTRIBUTIONS

1972 - 1977

- High Resolution Infrared Pyrometer
- Rotary Instrument Systems
- Optical Blade Flutter Monitors
- Drag Force Anemometer
- Gas Cooled Thermocouple
- Coaxial Thermocouple Miniaturization
- Laser Doppler Velocimeter Applications

AIR BREATHING ENGINE SYSTEMS R & T

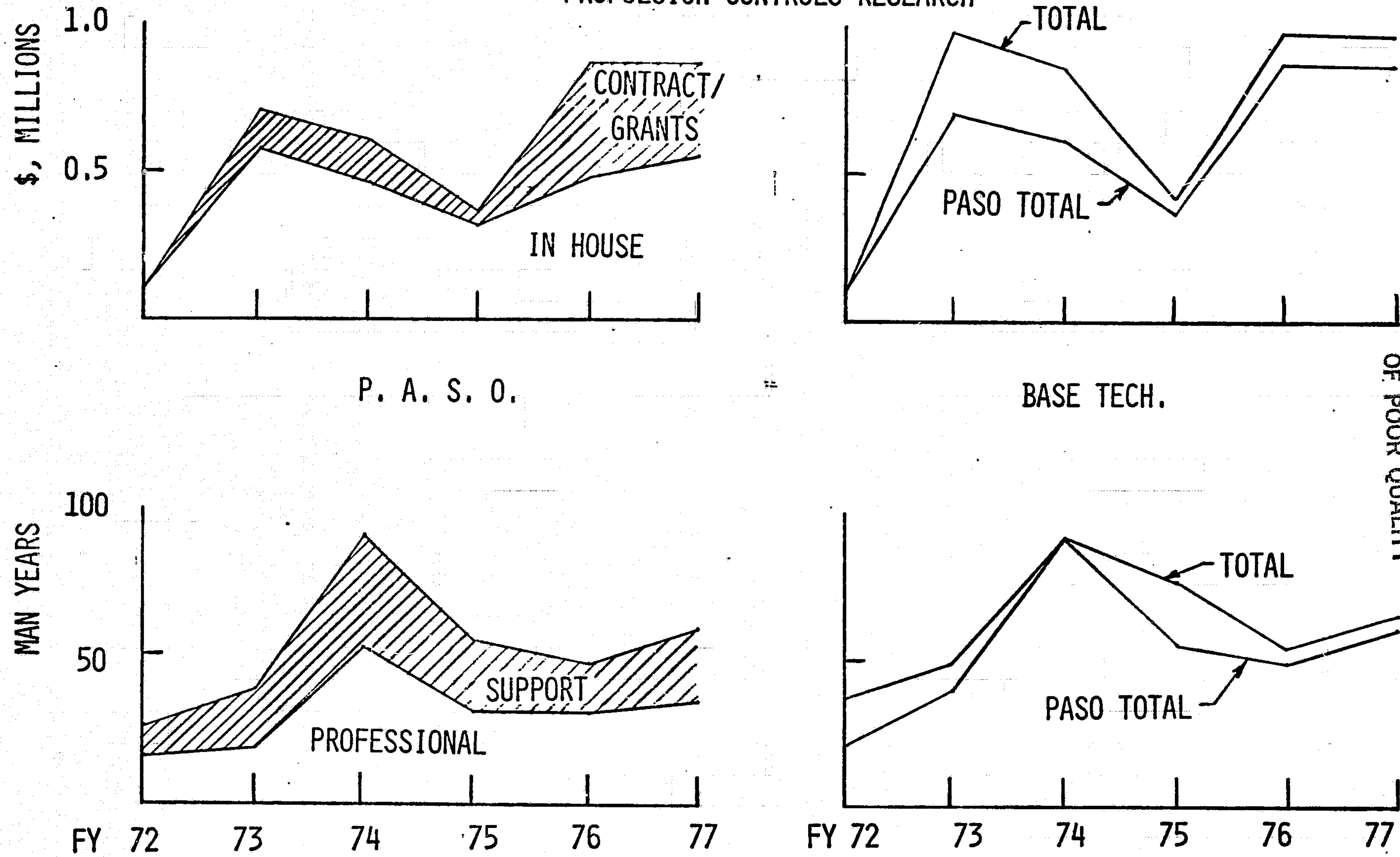
PROPULSION CONTROLS RESEARCH

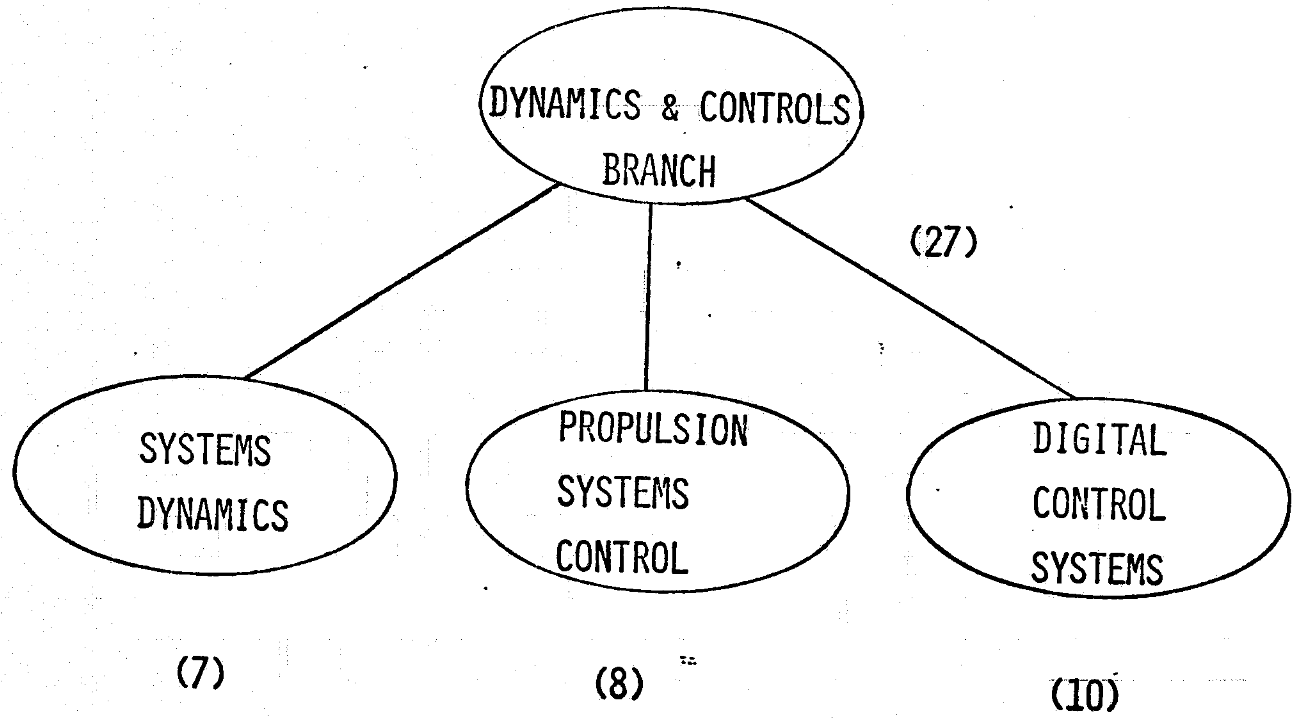
DANIEL DRAIN

WIND TUNNEL & FLIGHT DIVISION

R & T TRENDS

PROPULSION CONTROLS RESEARCH





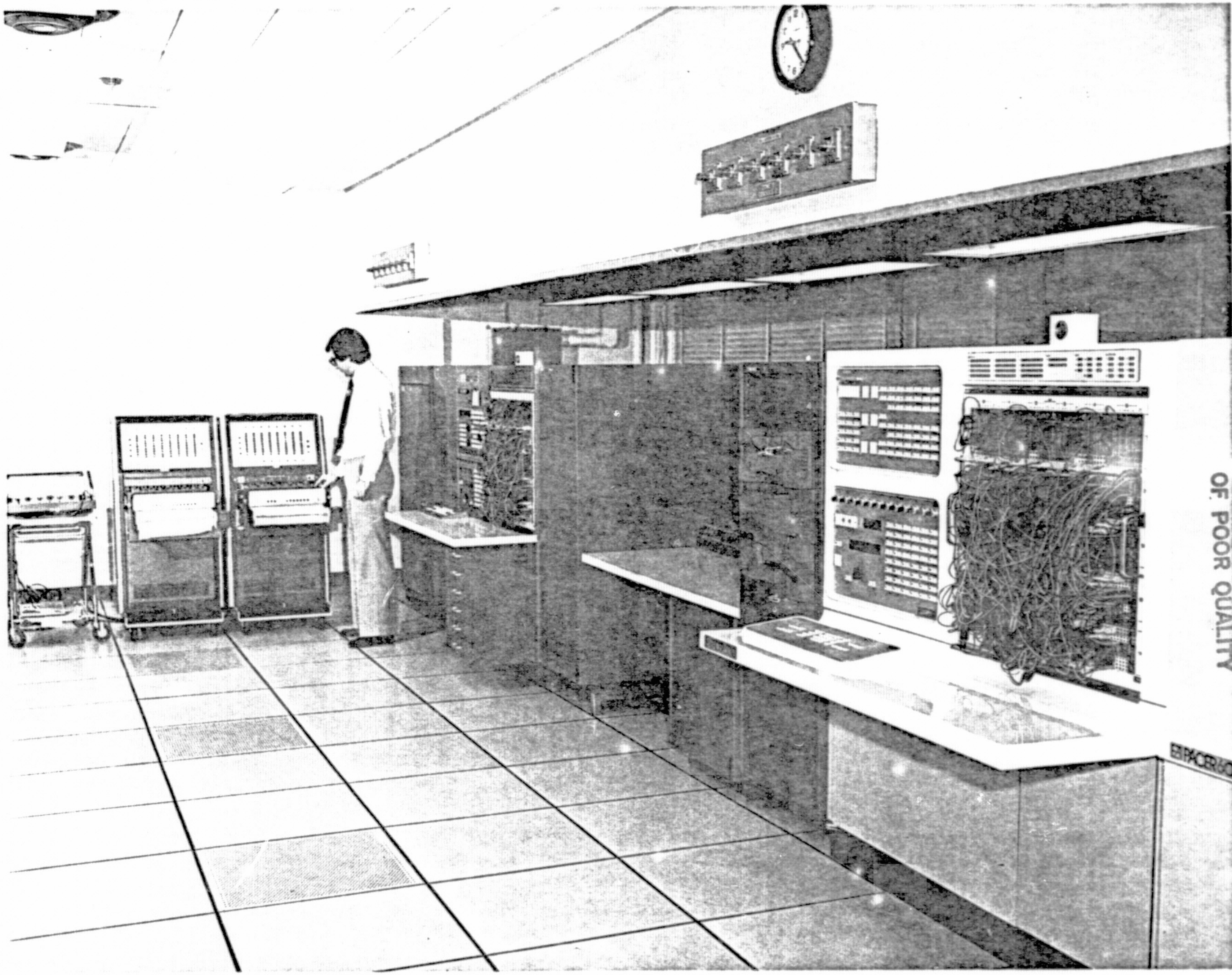
PRIMARY ACTIVITY

Systems Dynamics
- o SIMULATIONS
- o ENGINE COMPONENT DYNAMICS

Propulsion Systems Control
- o CONTROL HARDWARE
- o INLET DYNAMICS
- o SUPPORT { QCSEE, VSTOL

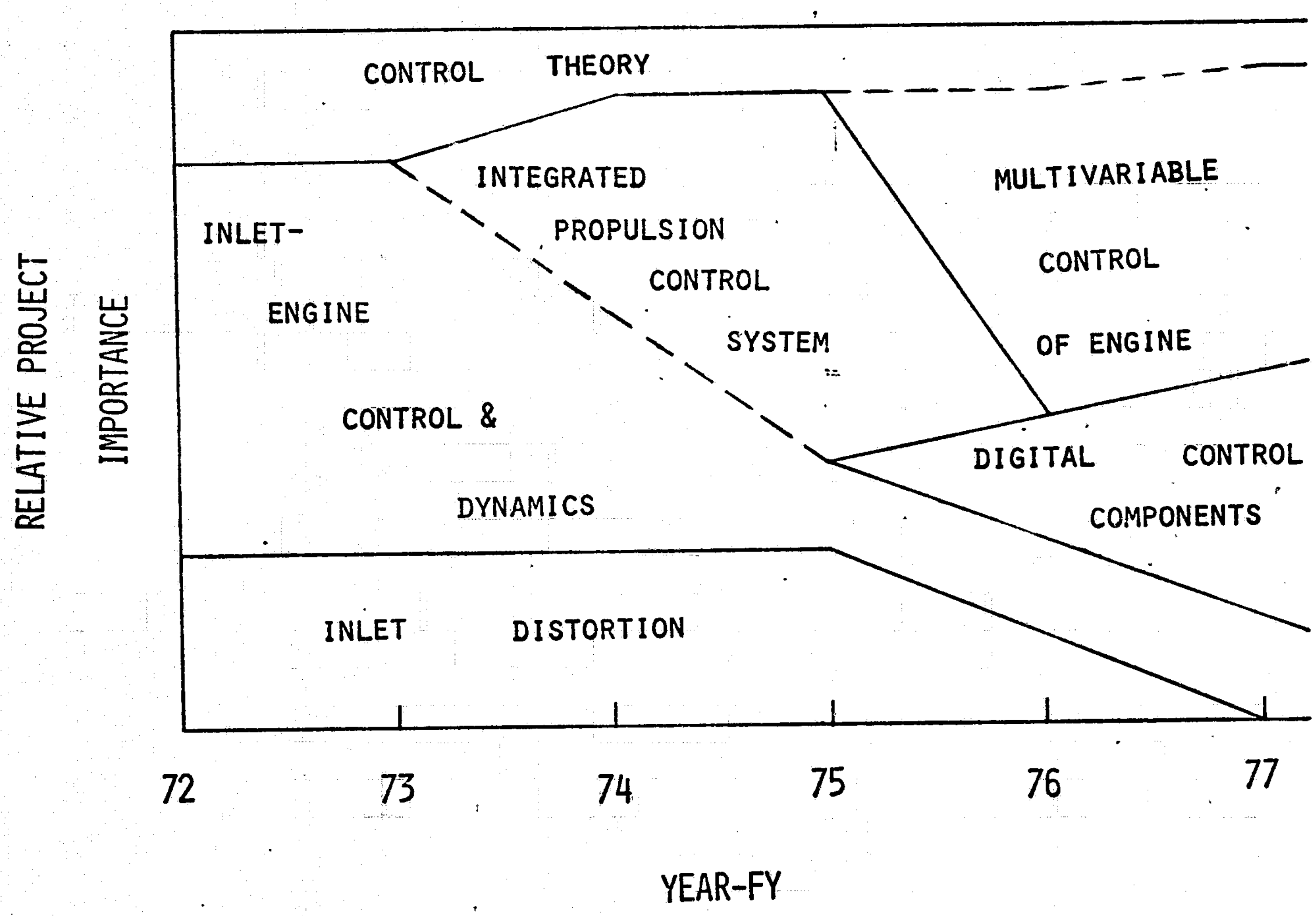
Digital Control Systems
- o CONTROL THEORY
- o DIGITAL CONTROL APPLICATIONS

NASA
C-76-4921



PRINCIPAL ELEMENTS OF THE PROGRAM

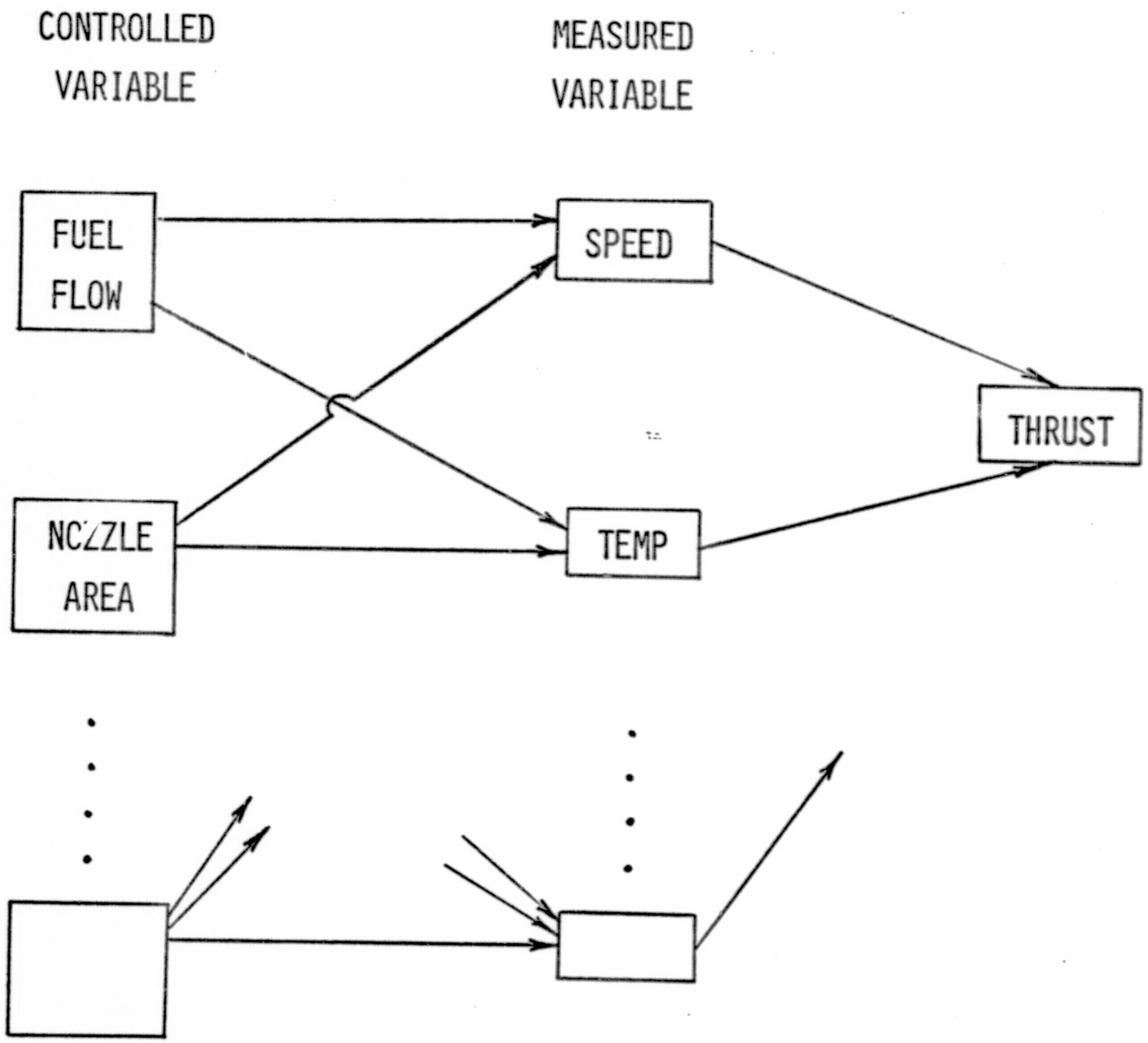
- PROPULSION SYSTEM DYNAMIC UNDERSTANDING
- CONTROL THEORY AND EVALUATION
- CONTROL USING DIGITAL COMPONENTS


CONTROL THEORY
INTEGRATED PROPULSION CONTROL SYSTEM
MULTIVARIABLE CONTROL OF ENGINE
INLET-ENGINE CONTROL & DYNAMICS
DIGITAL CONTROL COMPONENTS
INLET DISTORTION
RELATIVE PROJECT IMPORTANCE
72
73
74
75
76
77
YEAR-FY

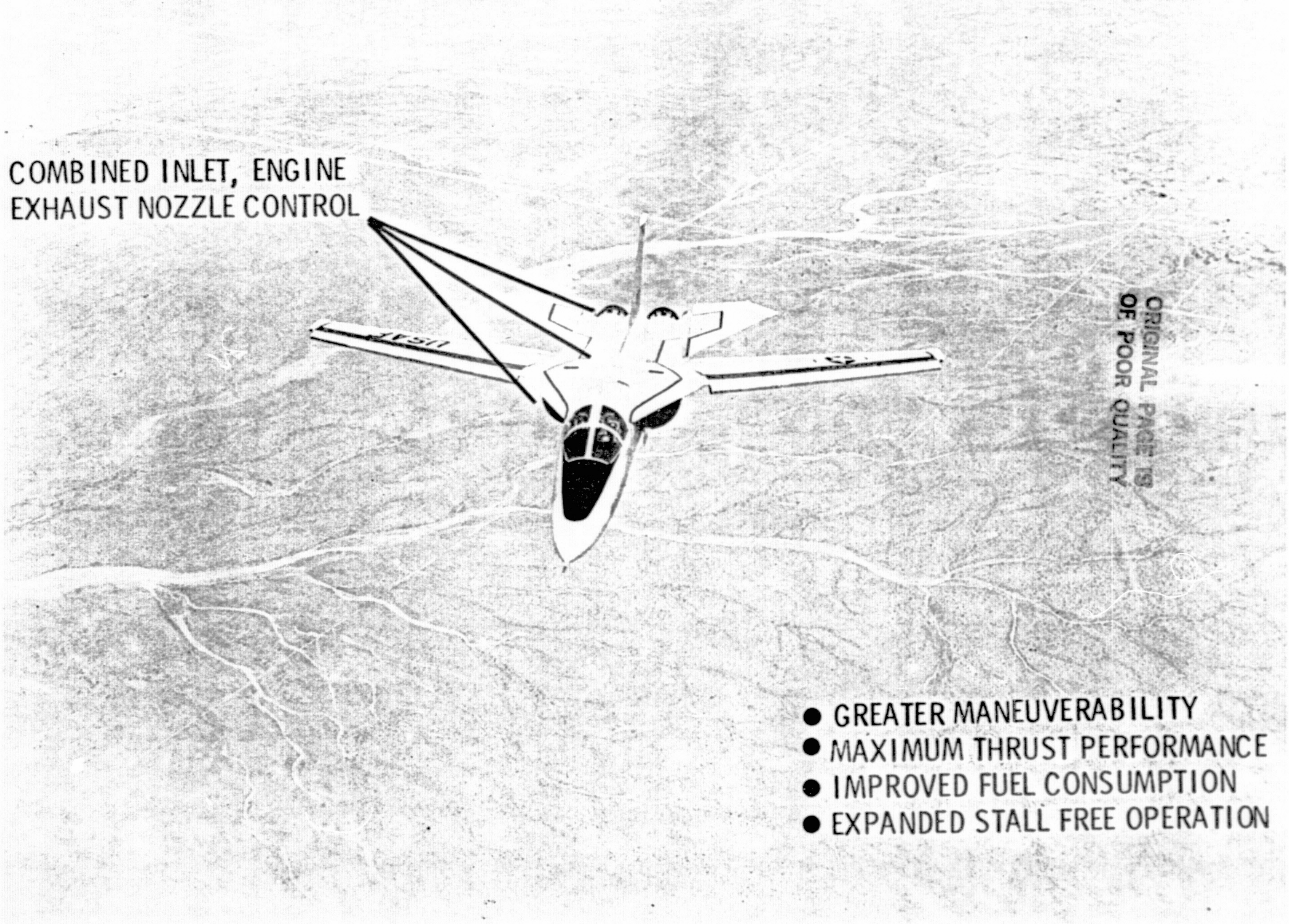
SIGNIFICANT CONTRIBUTIONS

- INLET/ENGINE AIRFLOW MATCHING
- INTEGRATED PROPULSION CONTROL SYSTEM
- MULTIVARIABLE CONTROL SYSTEMS

MULTIVARIABLE CONTROL

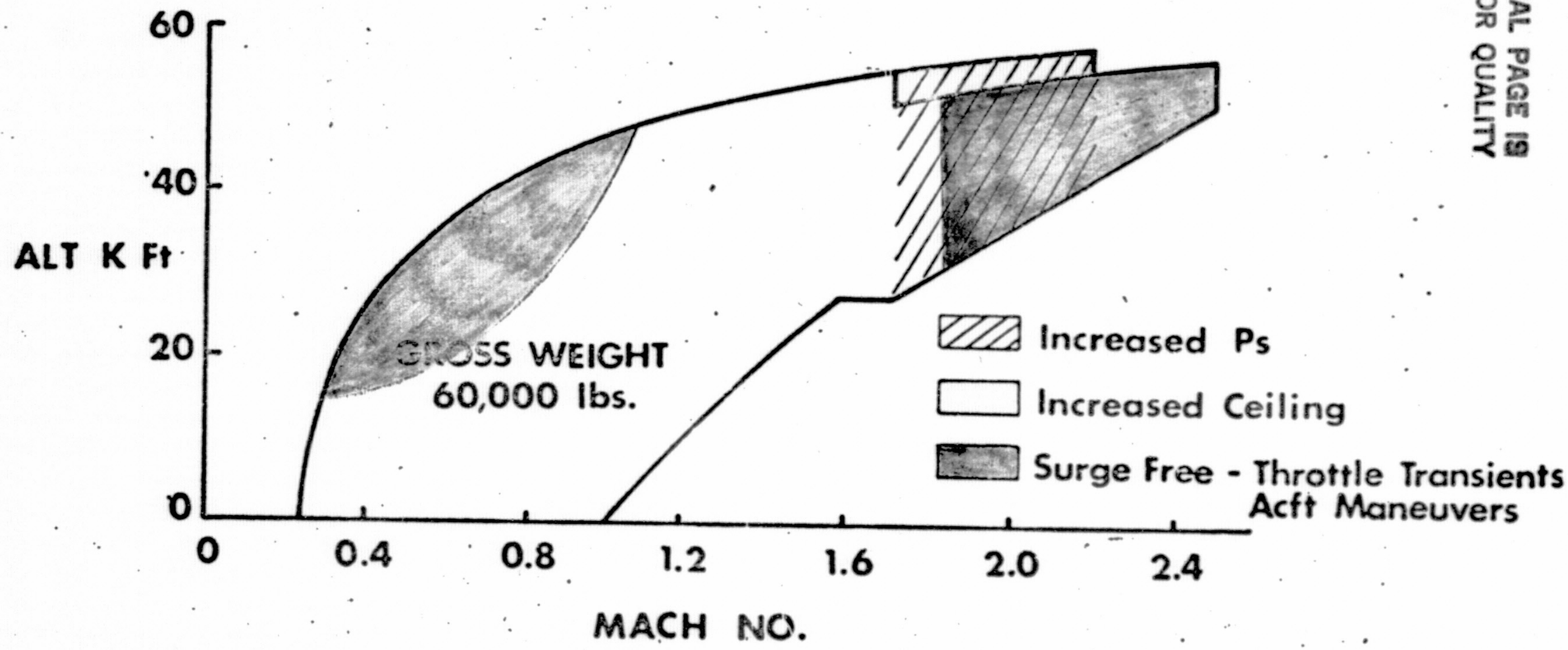


INTEGRATED PROPULSION CONTROL SYSTEM



IPCS

PERFORMANCE IMPROVEMENTS

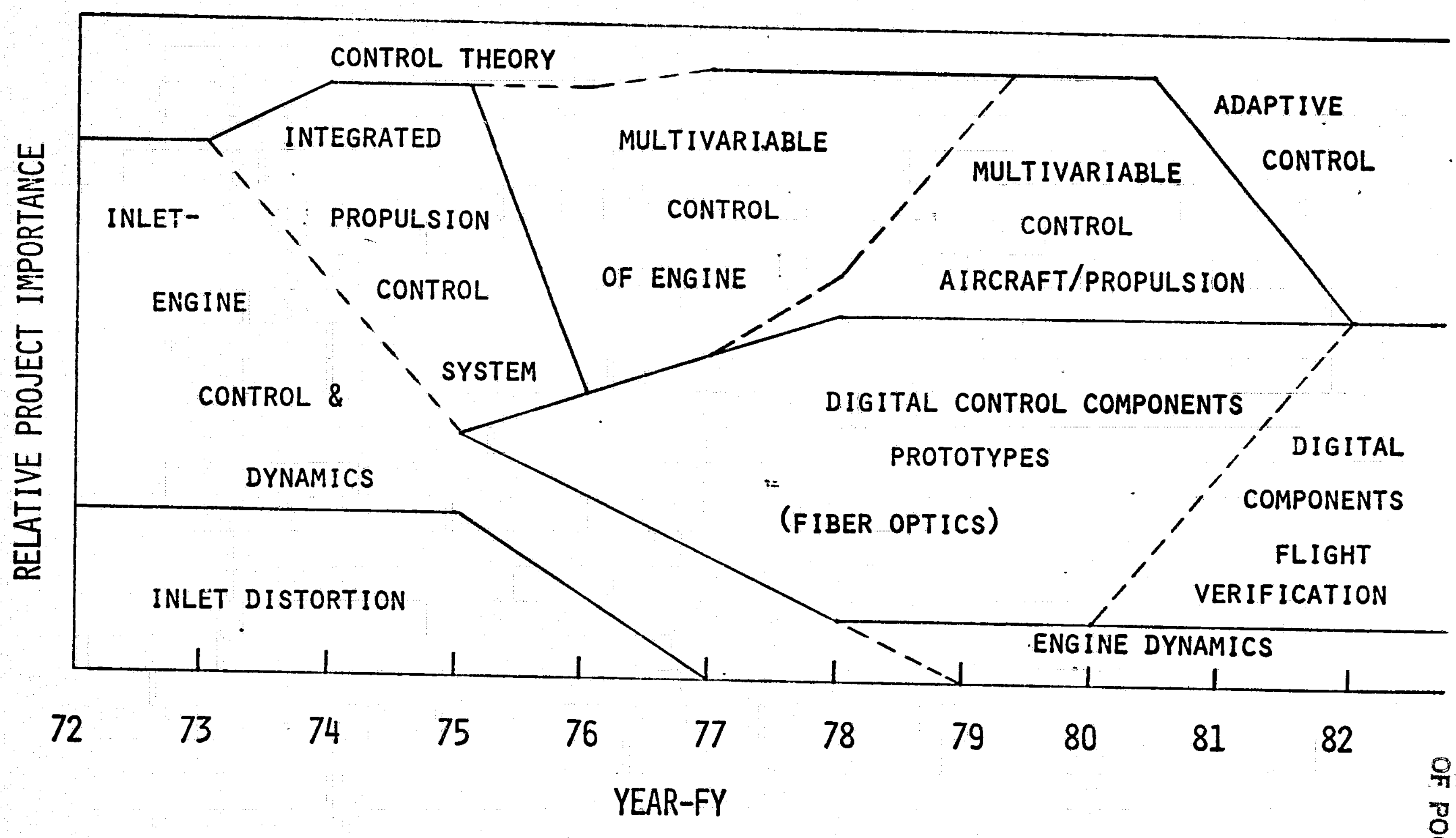


SPECIFIC OBJECTIVE: PROPULSION CONTROLS RESEARCH

DESCRIPTION: THE UNDERSTANDING AND PREDICTION OF PROPULSION SYSTEM DYNAMIC BEHAVIOR IS BEING IMPROVED SO THAT MAXIMUM PERFORMANCE CAN BE MAINTAINED SAFELY AND RELIABLY EVEN WITH SUDDEN AND UNEXPECTED DISTURBANCES.

TARGETS:

- DEVELOP METHODOLOGY TO EMPERICALLY PREDICT AIRCRAFT/INLET/ENGINE INTERACTIONS - FY 1979
- ASSESS MULTIVARIABLE CONTROL DESIGN METHODS FOR ADVANCED HIGH FLEXIBILITY ENGINES - FY 1980
- DEVELOP PRACTICAL AND RELIABLE DIGITAL CONTROL SYSTEMS, INCLUDING FIBEROPTRONICS - FY 1982

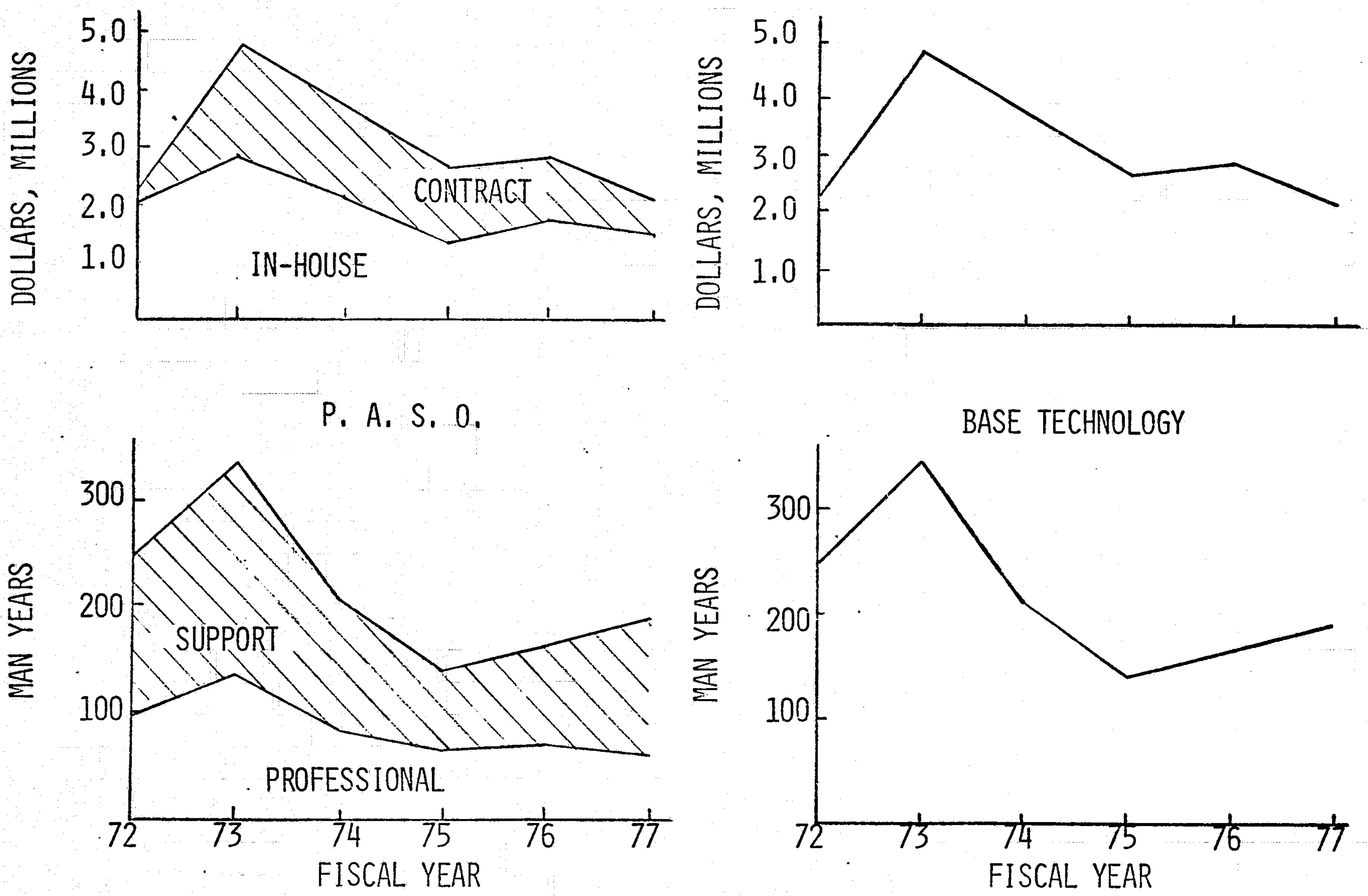

CONTROL THEORY
INTEGRATED PROPULSION CONTROL SYSTEM
MULTIVARIABLE CONTROL OF ENGINE
MULTIVARIABLE CONTROL AIRCRAFT/PROPULSION
ADAPTIVE CONTROL
INLET-ENGINE CONTROL & DYNAMICS
DIGITAL CONTROL COMPONENTS PROTOTYPES (FIBER OPTICS)
DIGITAL COMPONENTS FLIGHT VERIFICATION
INLET DISTORTION
ENGINE DYNAMICS
RELATIVE PROJECT IMPORTANCE
72
73
74
75
76
77
78
79
80
81
82
YEAR-FY

AIRBREATHING ENGINE SYSTEMS

FULL-SCALE ENGINE RESEARCH

ROSS WILLOH, AIRBREATHING ENGINES DIVISION

R & T TRENDS
FULL-SCALE ENGINE RESEARCH



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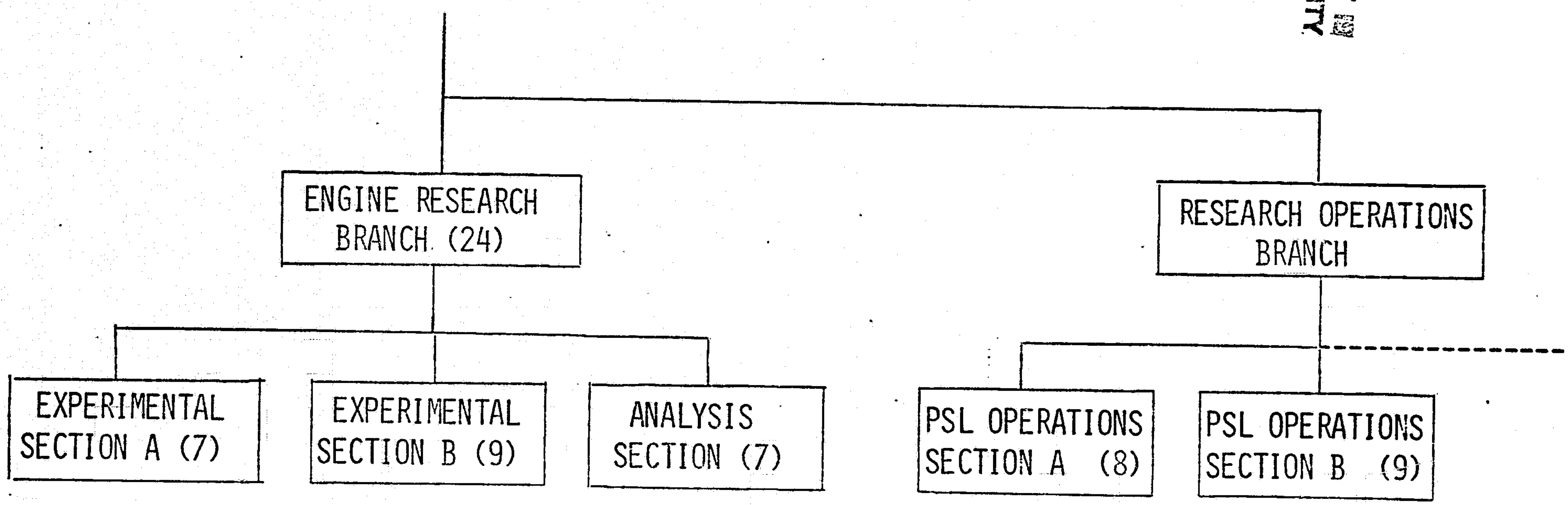
FULL-SCALE ENGINE RESEARCH

ORGANIZATION



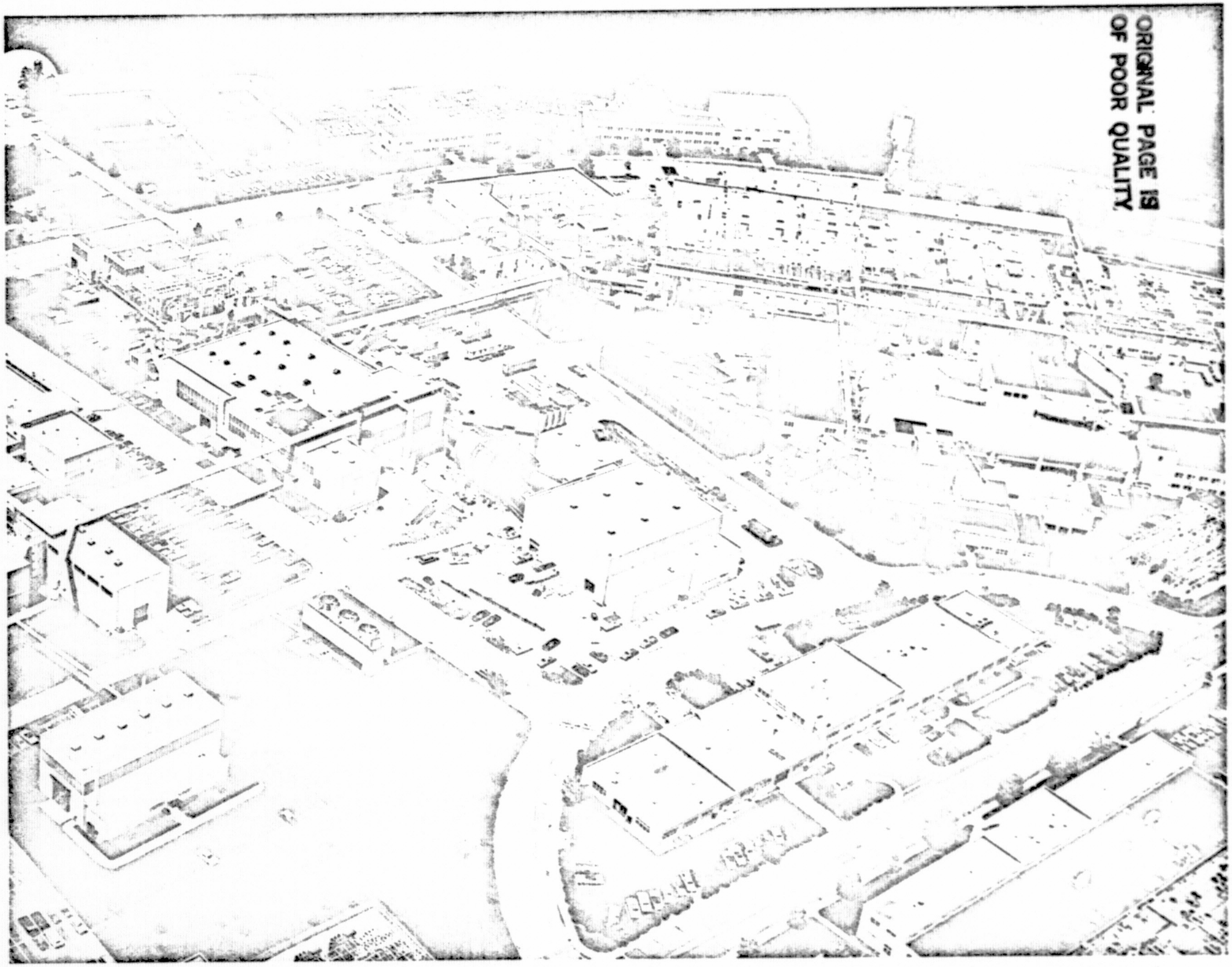
SPECIFIC OBJECTIVE: FULL-SCALE ENGINE RESEARCH

DESCRIPTION: EXPERIMENTAL AND ANALYTICAL EFFORTS ARE UNDERTAKEN TO DEVELOP IMPROVED UNDERSTANDING OF GOVERNING PHENOMENA AND TO PROVIDE AN EXPANDED TECHNOLOGY BASE FOR FUTURE ENGINE SYSTEM DEVELOPMENT. PARTICULAR EMPHASIS IS PLACED ON SEEKING UNDERSTANDING AND SOLUTIONS FOR THE DYNAMIC INTERACTION PROBLEMS ENCOUNTERED WHEN ENGINE COMPONENTS ARE COMBINED TO FORM AN ENGINE SYSTEM.

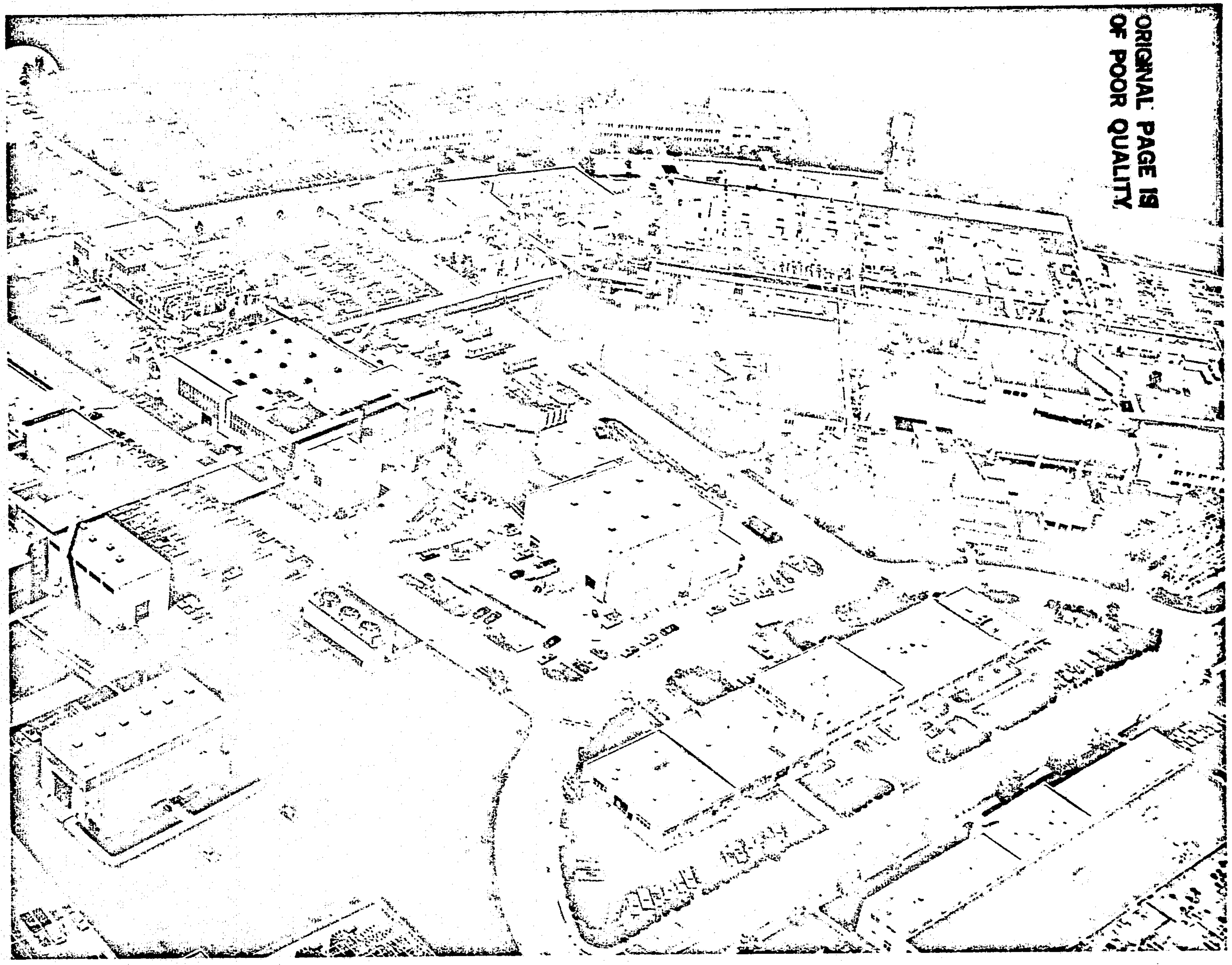
TARGETS:

- o INVESTIGATE AEROMECHANICAL INSTABILITY CHARACTERISTICS OF ADVANCED HIGH PERFORMANCE TURBOJET AND TURBOFAN ENGINES - 1980
- o DEVELOP IMPROVED TECHNIQUES FOR INTERNAL MIXING OF EXHAUST GAS STREAMS - 1979
- o DEVELOP IMPROVED ANALYTICAL TECHNIQUES FOR PREDICTION OF EFFECTS OF STEADY STATE AND DYNAMIC FLOW DISTORTIONS - 1981
- o PROVIDE EXPERIMENTAL AND ANALYTICAL SUPPORT FOR PROGRAMS ON ADVANCED ENGINE COMPONENTS, MODERN CONTROL CONCEPTS, IMPROVED MATERIALS, ETC. 1982

NASA
C-71-2827



NASA
C-71-2827



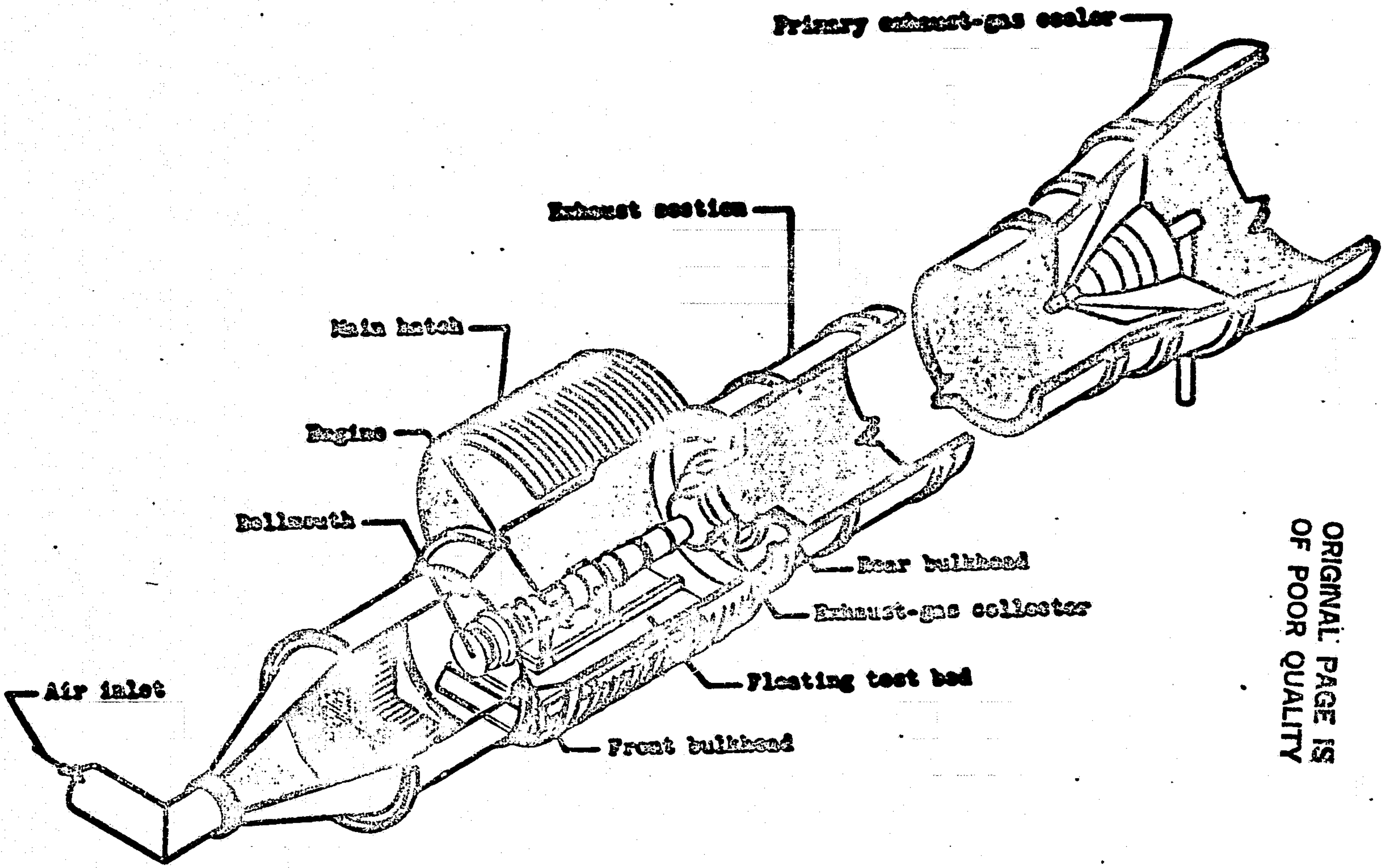


Figure 1. - Schematic diagram of altitude test chamber.

NASA

C-75-729

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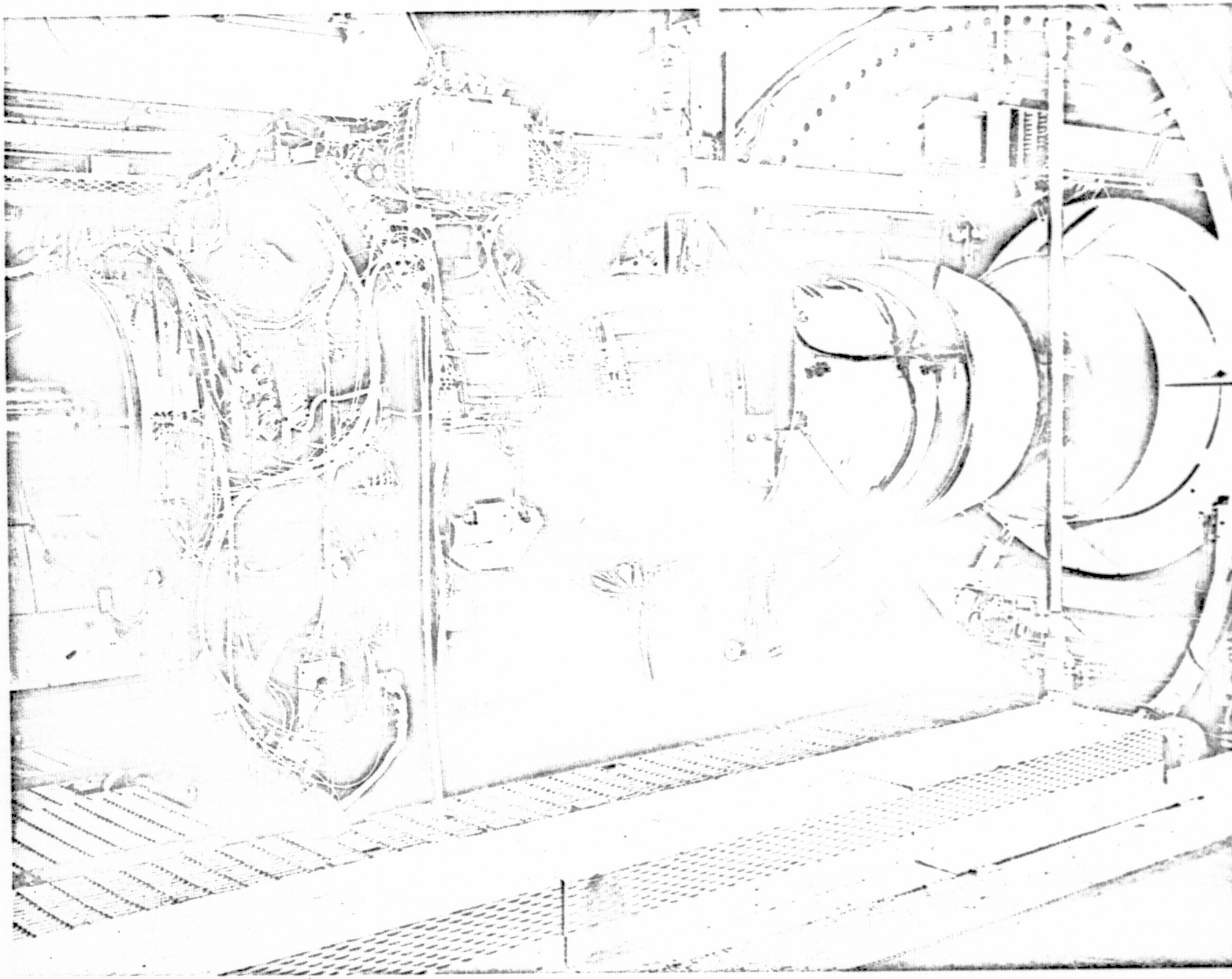
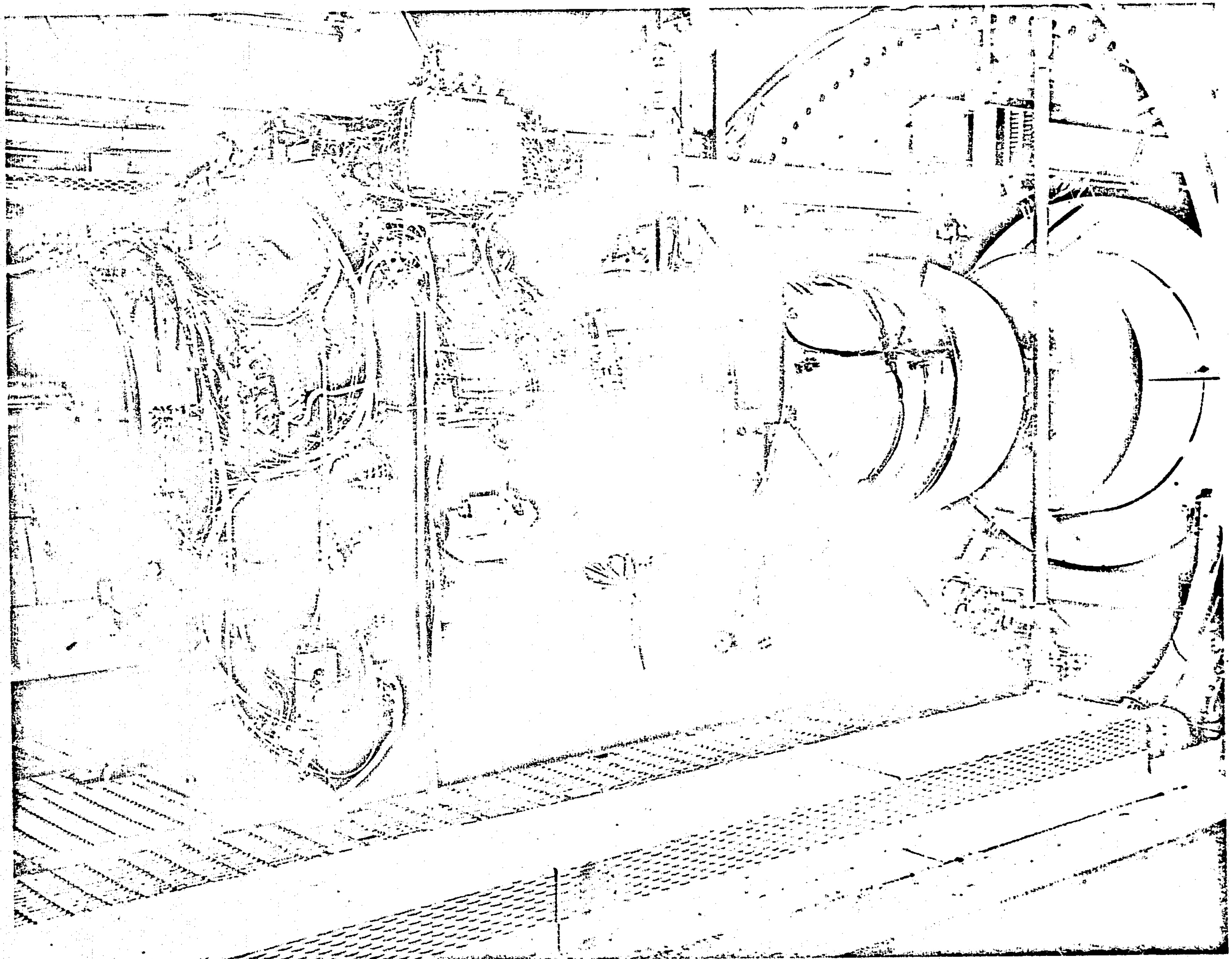


NASA

C-75-729



PSL AIR SERVICE CAPABILITY

SERVICE	CAPACITY (LB/SEC) PRESENT	CY '77
COMB. AIR		
60 PSIA	460	460
165 PSIA	386	386
DRYING CAPACITY (<.5 GR.)	230	460
COMB. AIR TEMP.		
650° F	230	230
1200° F PSL 3/4 ONLY	280	280
- 35° F 10 PSIA	100	
- 100° F 25 PSIA		
PSL 1/2		130
PSL 3/4		386
EXH. CAPABILITY (AT MACHINES)		
50,000 FT (LESS AT	220	220
70,000 FT TEST CHAMBERS)	90	90

-65°
460#

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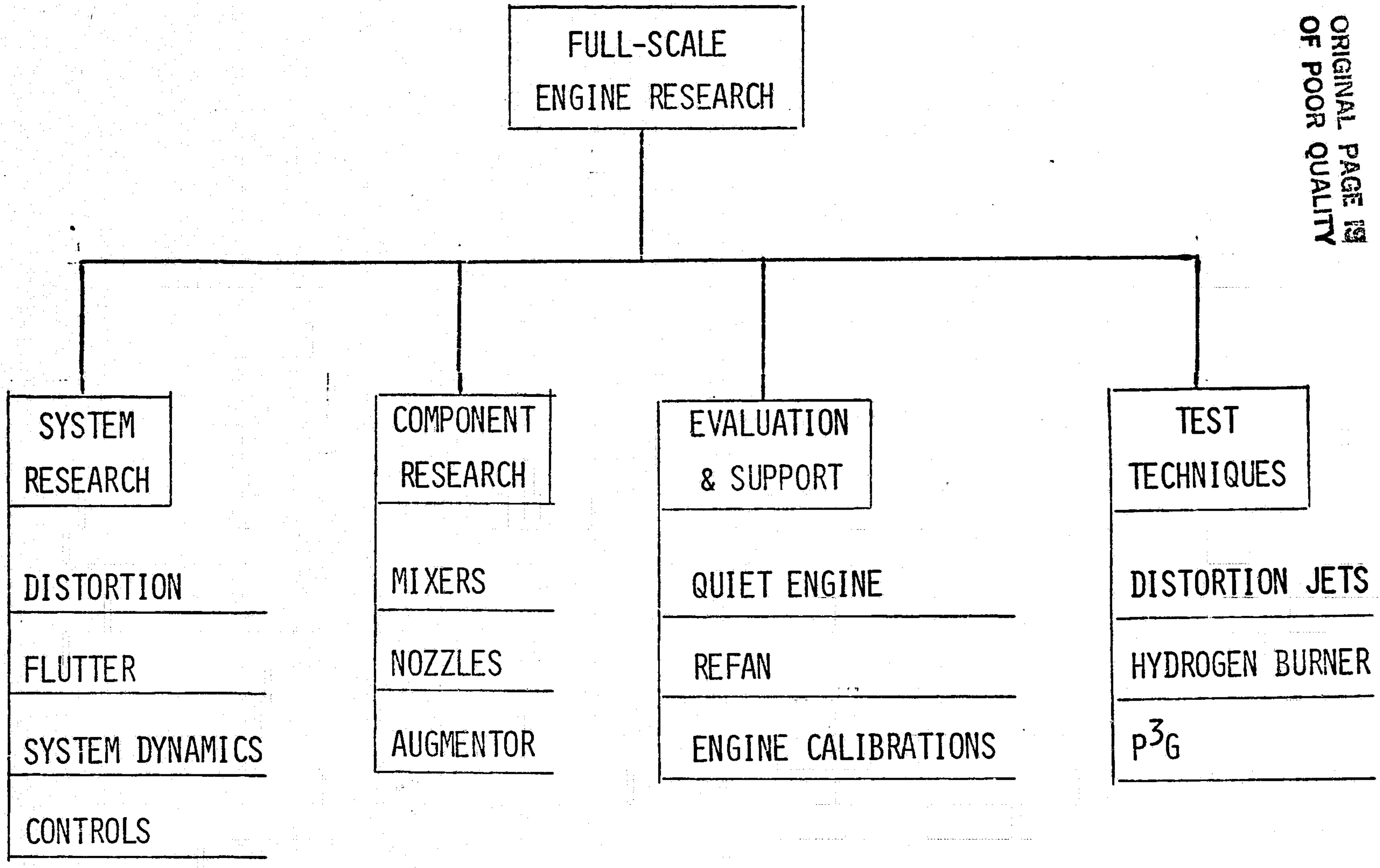

FULL-SCALE ENGINE RESEARCH
SYSTEM RESEARCH
DISTORTION
FLUTTER
SYSTEM DYNAMICS
CONTROLS
COMPONENT RESEARCH
MIXERS
NOZZLES
AUGMENTOR
EVALUATION & SUPPORT
QUIET ENGINE
REFAN
ENGINE CALIBRATIONS
TEST TECHNIQUES
DISTORTION JETS
HYDROGEN BURNER
P3G

FULL-SCALE ENGINE RESEARCH

JOINT AIR FORCE/NASA FSER PROGRAM

OBJECTIVE

IMPROVE BASIC UNDERSTANDING OF SYSTEMS AND COMPONENTS IN THE ENGINE ENVIRONMENT

ESTABLISH AND IMPROVE DESIGN CRITERIA FOR FUTURE ENGINE DEVELOPMENT

GROUND RULES

- ENGINES TO BE ALLOCATED BY AIR FORCE FROM ADVANCED DEVELOPMENT PROGRAMS
- PROGRAM OBJECTIVES WILL BE ESTABLISHED JOINTLY BY AIR FORCE APL AND NASA LERC
- NASA WILL PROVIDE RESOURCES FOR PROGRAM EXECUTION AND REPORTING

PROGRAMS

- DEVOTED TO AREAS WHERE SYSTEMATIC FULL-SCALE TESTING OF HIGHLY-INSTRUMENTED ENGINES CAN CONTRIBUTE TO FUNDAMENTAL UNDERSTANDING AND FUTURE DESIGN
- ENGINES ARE REGARDED AS FACILITIES ON WHICH A VARIETY OF PROGRAMS ARE CONDUCTED
- DO NOT INCLUDE DEVELOPMENT PROBLEM SOLUTION OR CIP WORK

FULL-SCALE ENGINE RESEARCH
CURRENT PRIMARY PROJECT AREAS

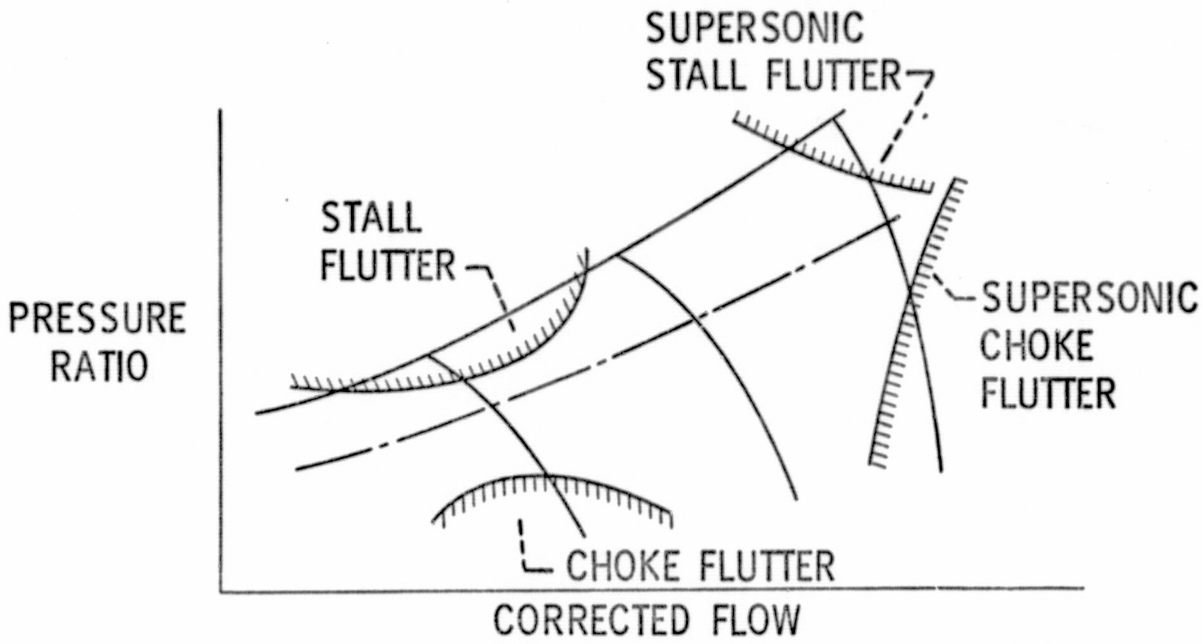
- FLUTTER (F100, J85-21)
- DISTORTION (TF30, F100, TF34)
- ENGINE DYNAMICS AND SIMULATION (J85-13, TF30, F100, TF34)
- HIGH ALTITUDE PERFORMANCE (TF34)
- EXHAUST GAS MIXERS (TF30, TF34)
- TIP CLEARANCE (TF34)

FULL-SCALE ENGINE RESEARCH

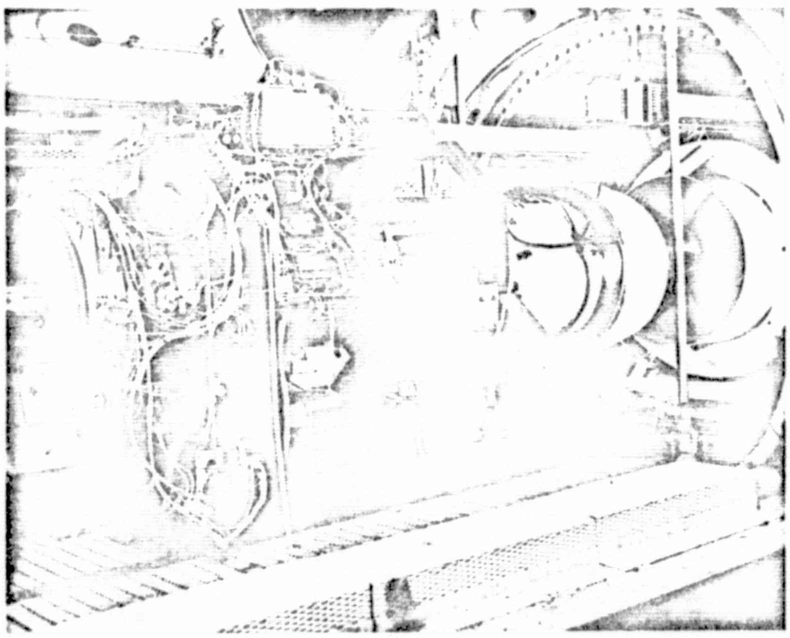
CURRENT SUPPORT PROJECT AREAS

- MATERIALS & PROCESSES
  - THERMAL BARRIER COATING ON F100 1ST STG. TURBINE BLADES
- AUGMENTORS (F100)
- EMISSIONS (TF34)
- EXHAUST NOZZLES (J85-13)
- CONTROLS (F100)
- INSTRUMENTATION
- ENGINE BALANCING (F100)
- THRUST METER (TF30, F100)

FAN AND COMPRESSOR BLADING FLUTTER DATA BANK

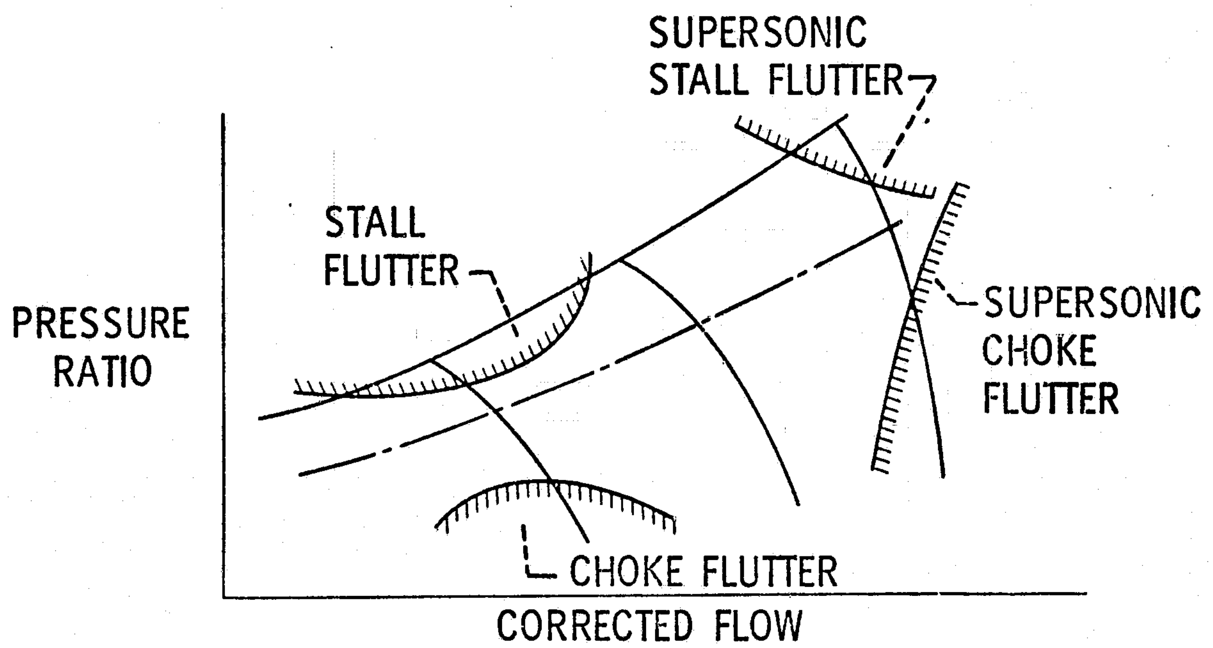


TYPICAL FLUTTER REGIONS SHOWN ON COMPRESSOR MAP

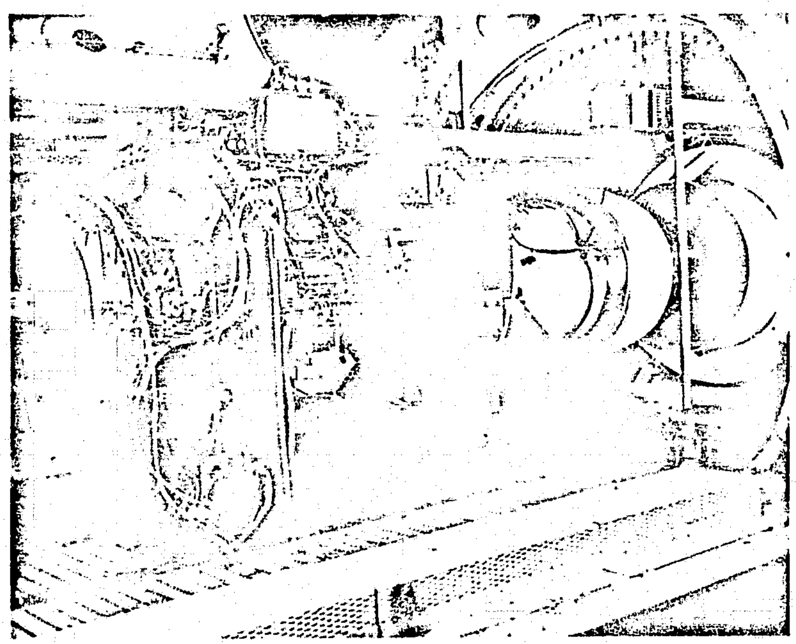


F100 ENGINE INSTRUMENTED FOR FLUTTER
TESTING IN PSL-1

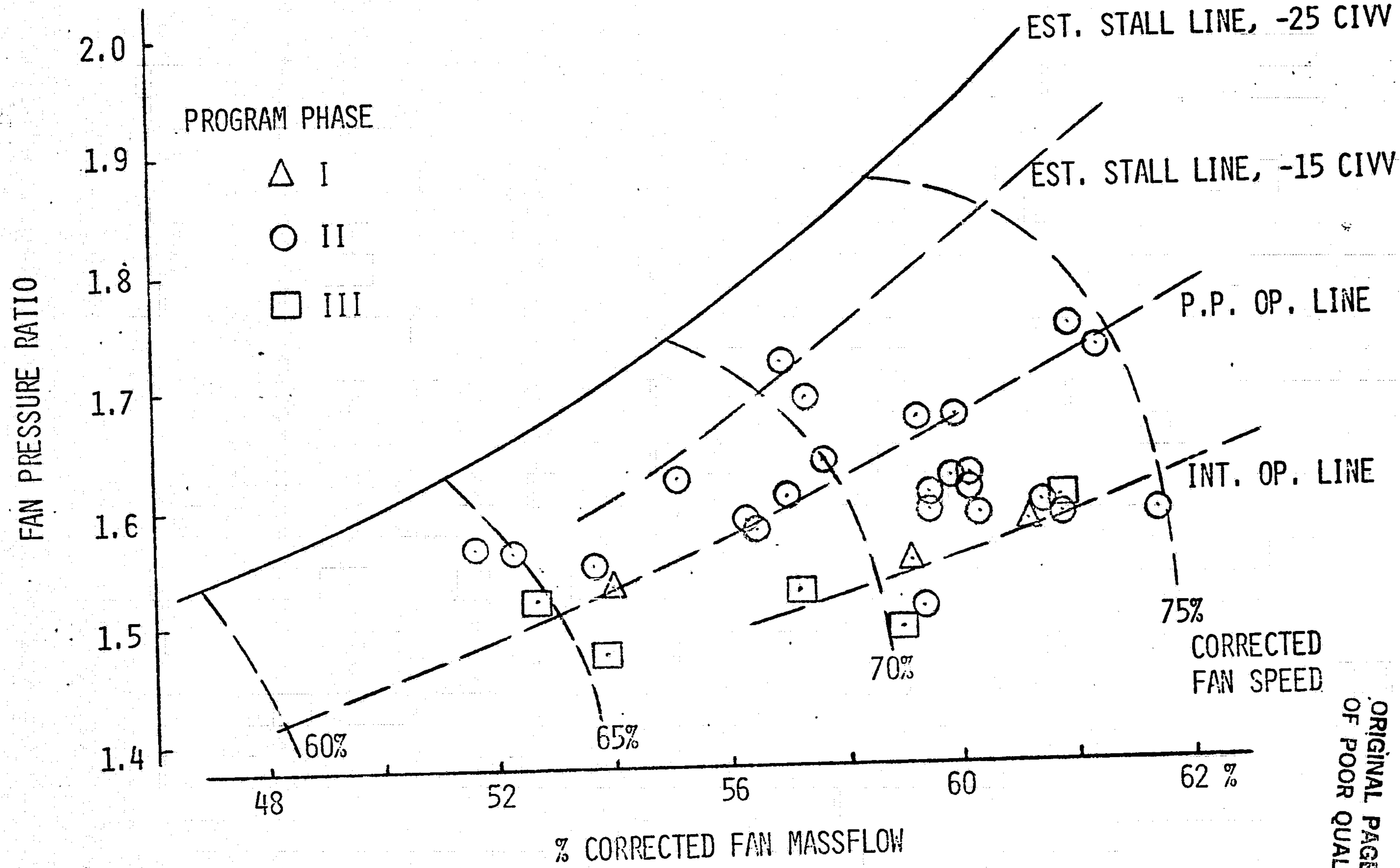
FAN AND COMPRESSOR BLADING FLUTTER DATA BANK



TYPICAL FLUTTER REGIONS SHOWN ON COMPRESSOR MAP

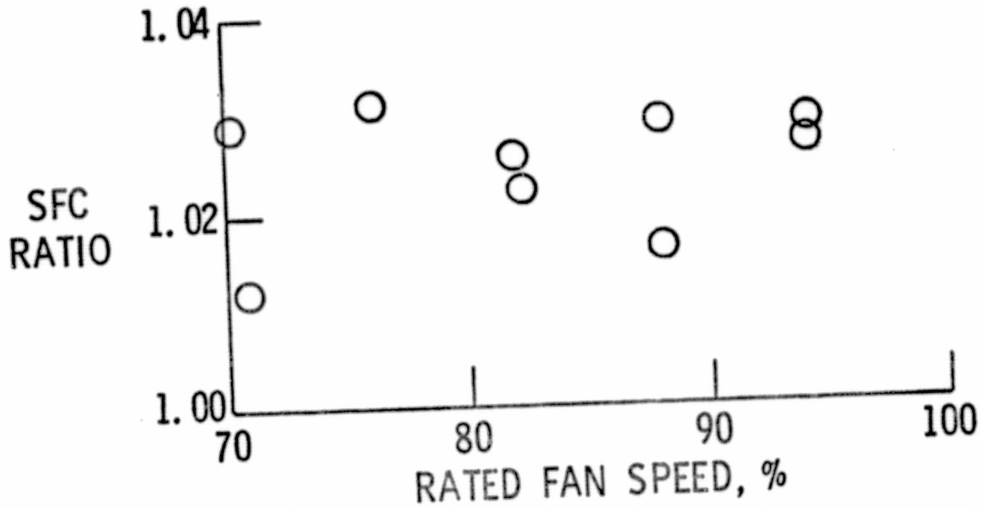


F100 ENGINE INSTRUMENTED FOR FLUTTER
TESTING IN PSL-1

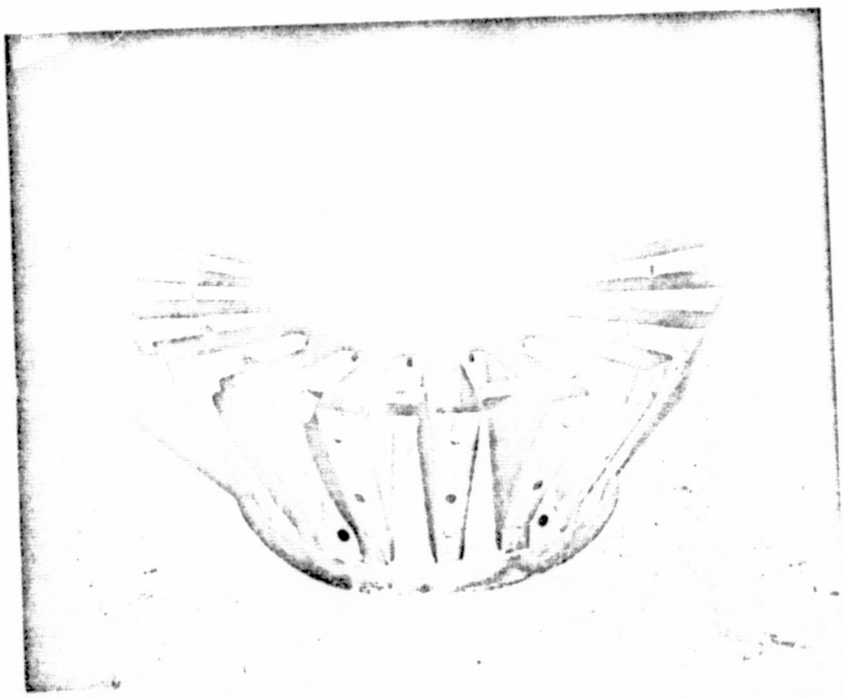


F-100 FX213 FAN FLUTTER DATA

TURBOFAN EXHAUST GAS MIXER



MIXER PERFORMANCE



MIXER

FULL-SCALE ENGINE RESEARCH

DISTORTION PROGRAM STATUS

- o HAVE ESTABLISHED EXTENSIVE EXPERIMENTAL DATA BANK
- o CONTRACT ANALYSIS STUDIES
- o CURRENT TF30 PROGRAM
- o ENGINE SYSTEM RESPONSES TO HIGH FREQUENCY DISTURBANCES
- o TEST TECHNIQUES
- o FUTURE PROGRAMS

FULL-SCALE ENGINE RESEARCH

CURRENT SUPPORT PROJECT AREAS

- o MATERIALS & PROCESSES
  - -THERMAL BARRIER COATING ON F100 1ST STG. TURBINE BLADES
- o AUGMENTORS (F100)
- o EMISSIONS (TF34)
- o EXHAUST NOZZLES (J85-13)
- o CONTROLS (F100)
- o INSTRUMENTATION
- o ENGINE BALANCING (F100)
- o THRUST METER (TF30, F100)

FULL-SCALE ENGINE RESEARCH

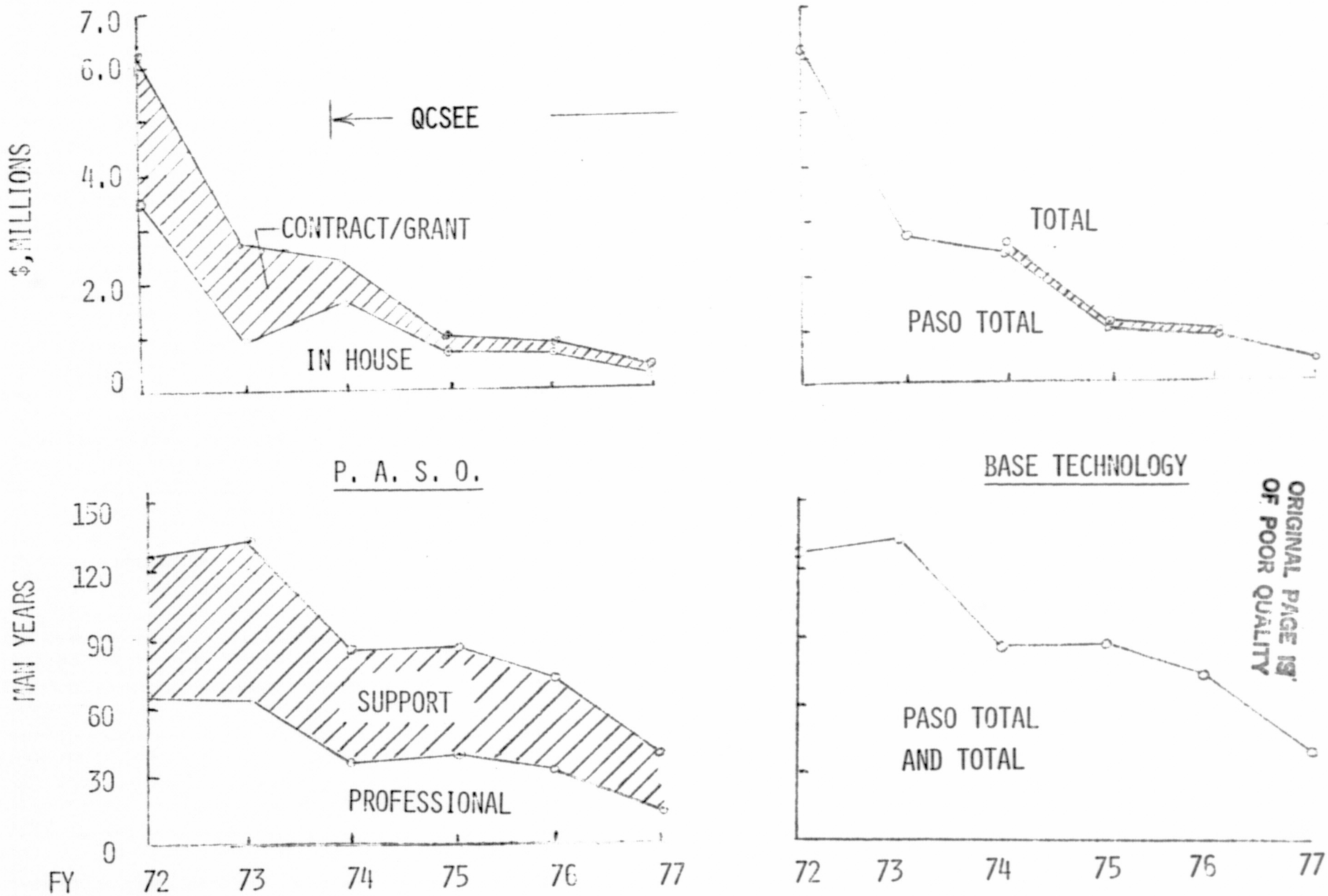
ACCOMPLISHMENTS

- ESTABLISHED EXTENSIVE DISTORTION DATA BANK
- DEVELOPED DISTORTION JET AND HYDROGEN BURNER SYSTEMS FOR DISTORTION TESTING
- GENERATED FULL-SCALE ALTITUDE DATA FOR AN EXHAUST GAS MIXER
- ESTABLISHED IN-HOUSE CAPABILITY FOR FLUTTER TESTING AND DATA ANALYSIS
- GENERATED HEAT TRANSFER DATA AND DATA CORRELATIONS FROM COOLED PLUG NOZZLE TESTS
- INVESTIGATED AUGMENTOR CONFIGURATIONS AND DEVELOPED A HYDROGEN BURNER SYSTEM TO RAISE TURBINE DISCHARGE TEMPERATURE TO SIMULATE ADVANCED ENGINES

DISCIPLINE/SUB-PROG.	AIRBREATHING ENGINE SYSTEMS
SPECIFIC OBJECTIVE	V/STOL PROPULSION RESEARCH
PRESENTER	ROGER W. LUIDENS, CHIEF LOW SPEED AERODYNAMICS BRANCH WIND TUNNEL AND FLIGHT DIVISION

R&T TRENDS

V/STOL PROPULSION RESEARCH



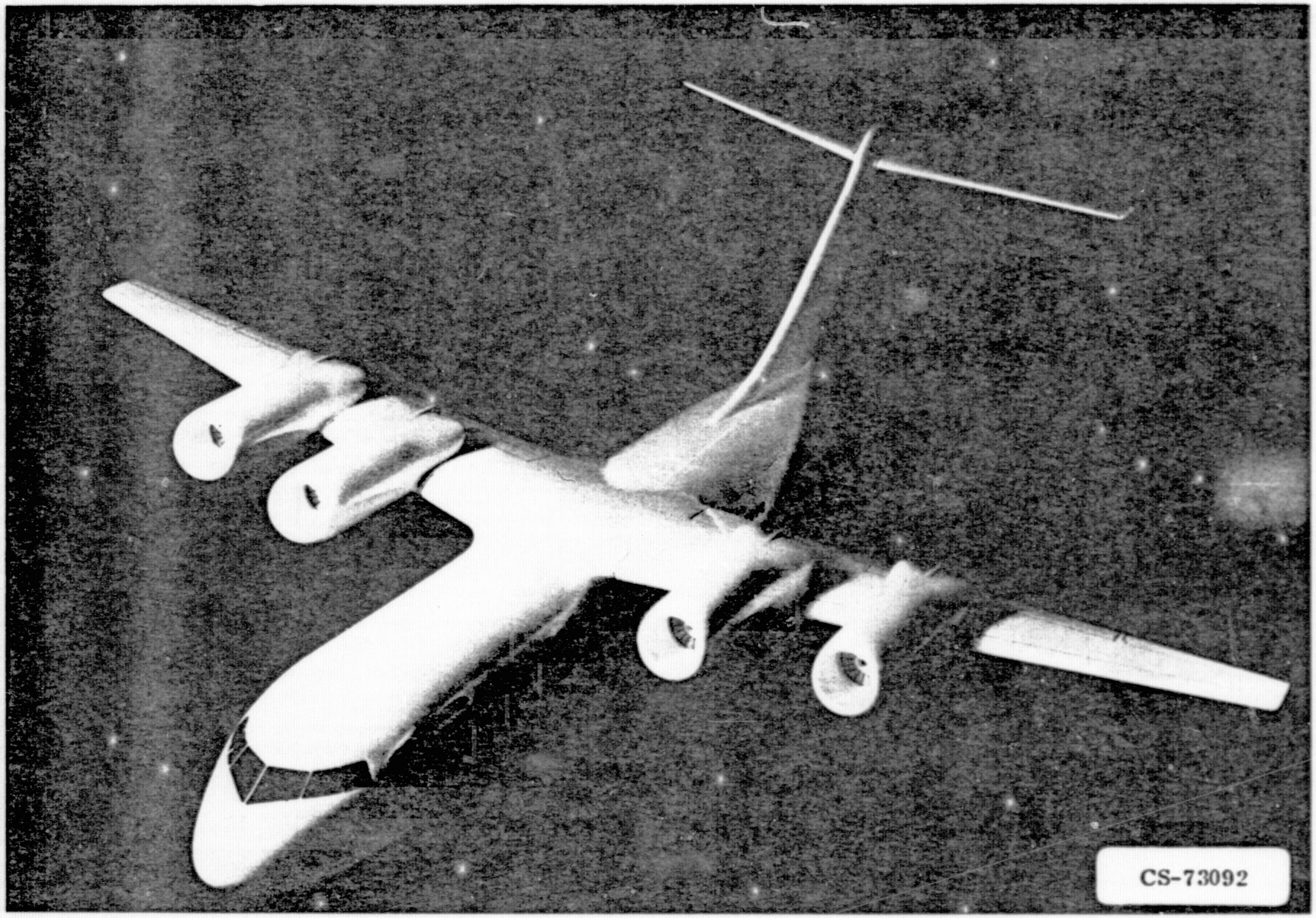
- SPECIFIC OBJECTIVE: V/STOL PROPULSION RESEARCH

DESCRIPTION: ANALYTICAL AND EXPERIMENTAL INVESTIGATIONS WILL BE CONDUCTED TO PROVIDE A TECHNOLOGY BASE FOR ADVANCED TURBINE ENGINE COMPONENTS/ SYSTEMS UNIQUE TO AND REQUIRED BY FUTURE STOL AND VTOL AIRCRAFT.

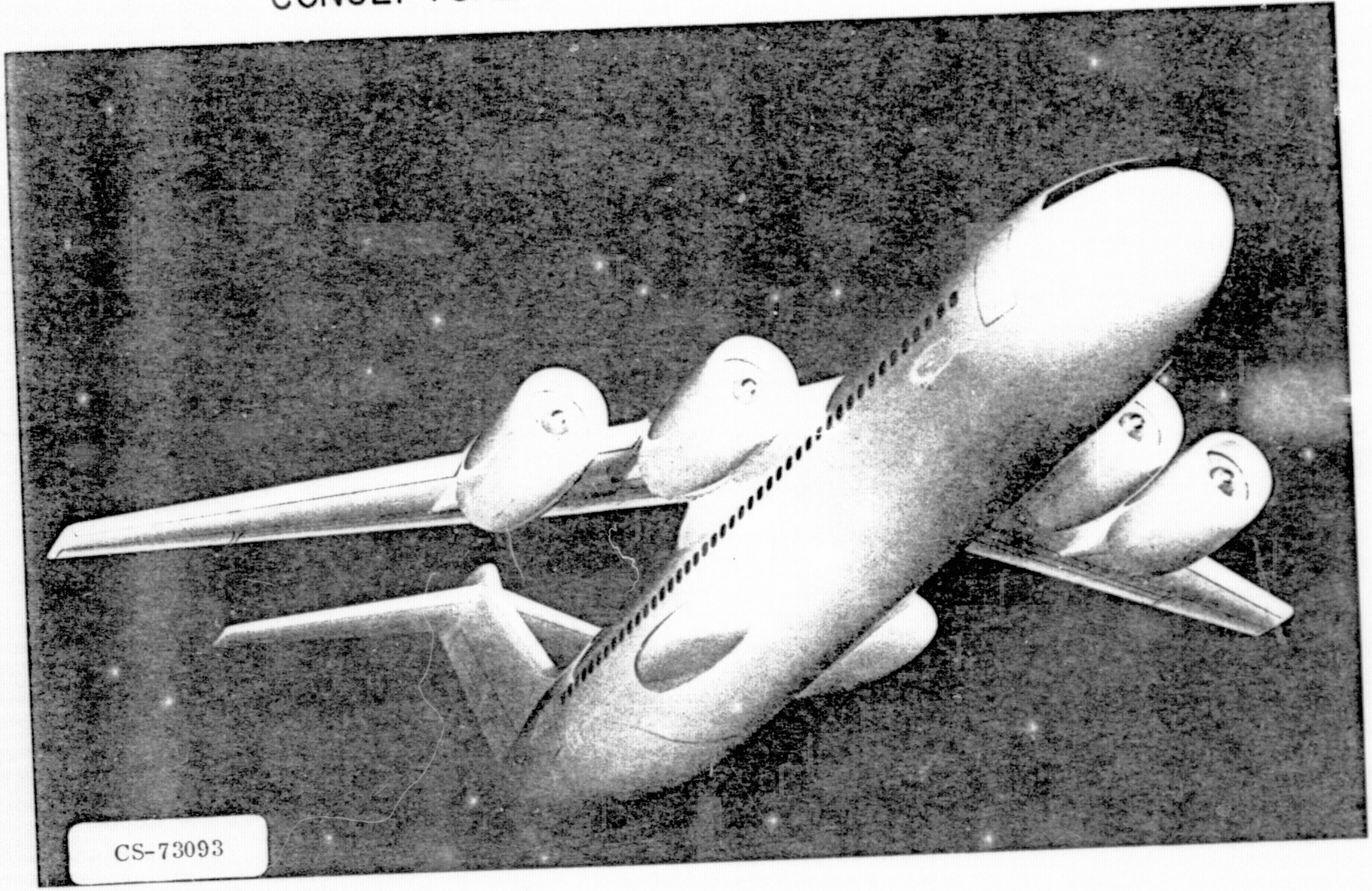
TARGETS:

1. INVESTIGATE LIFT CRUISE FAN PROPULSION CONCEPTS - FY 1980
2. DEVELOP ADVANCED POWER TRANSFER COMPONENTS/ SYSTEMS - FY 1982
3. EVALUATE ADVANCED CONTROL CONCEPTS FOR V/STOL PROPULSION SYSTEMS - FY 1982

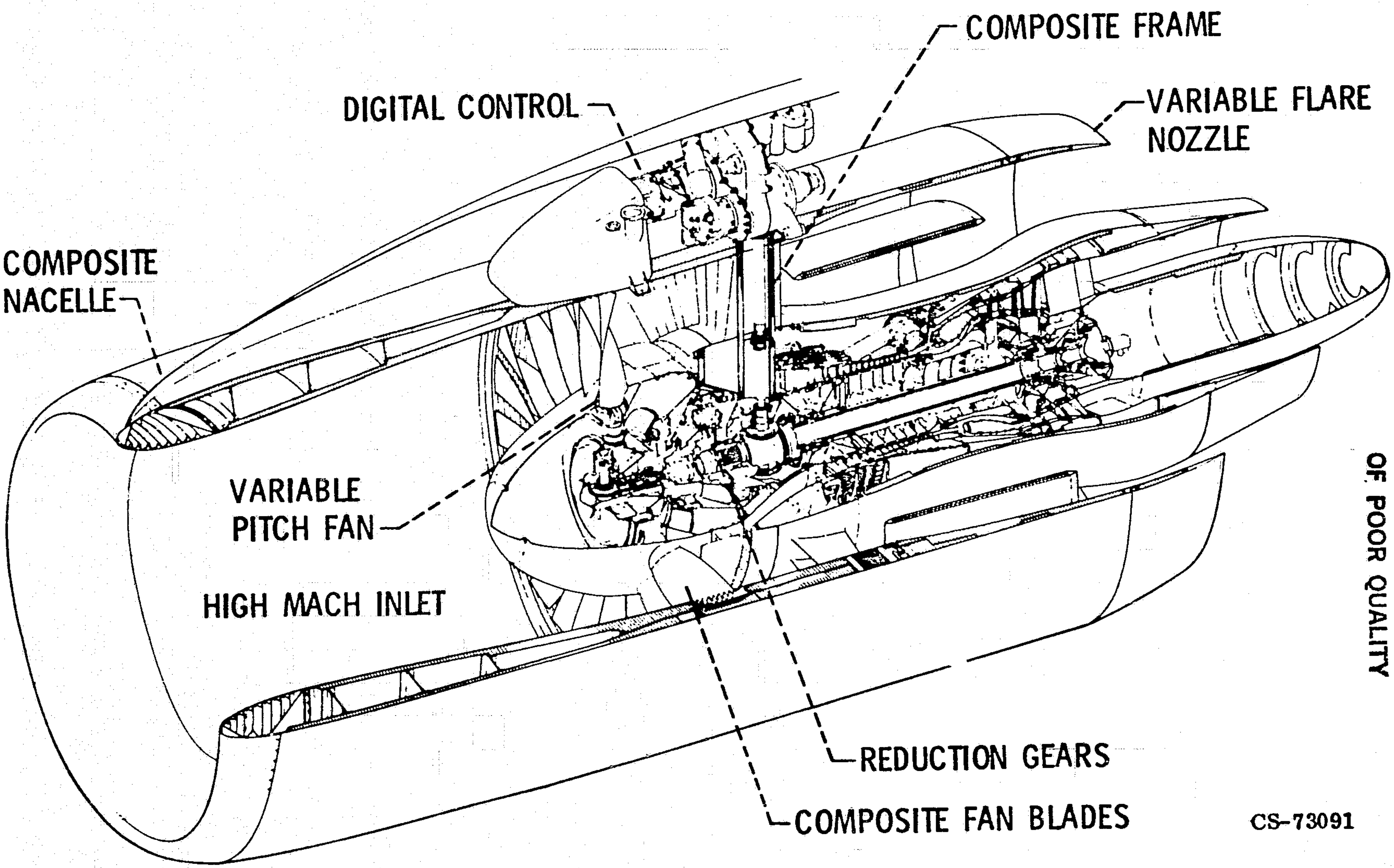
CONCEPTUAL OTW SHORT-HAUL AIRCRAFT



CONCEPTUAL UTW SHORT-HAUL AIRCRAFT

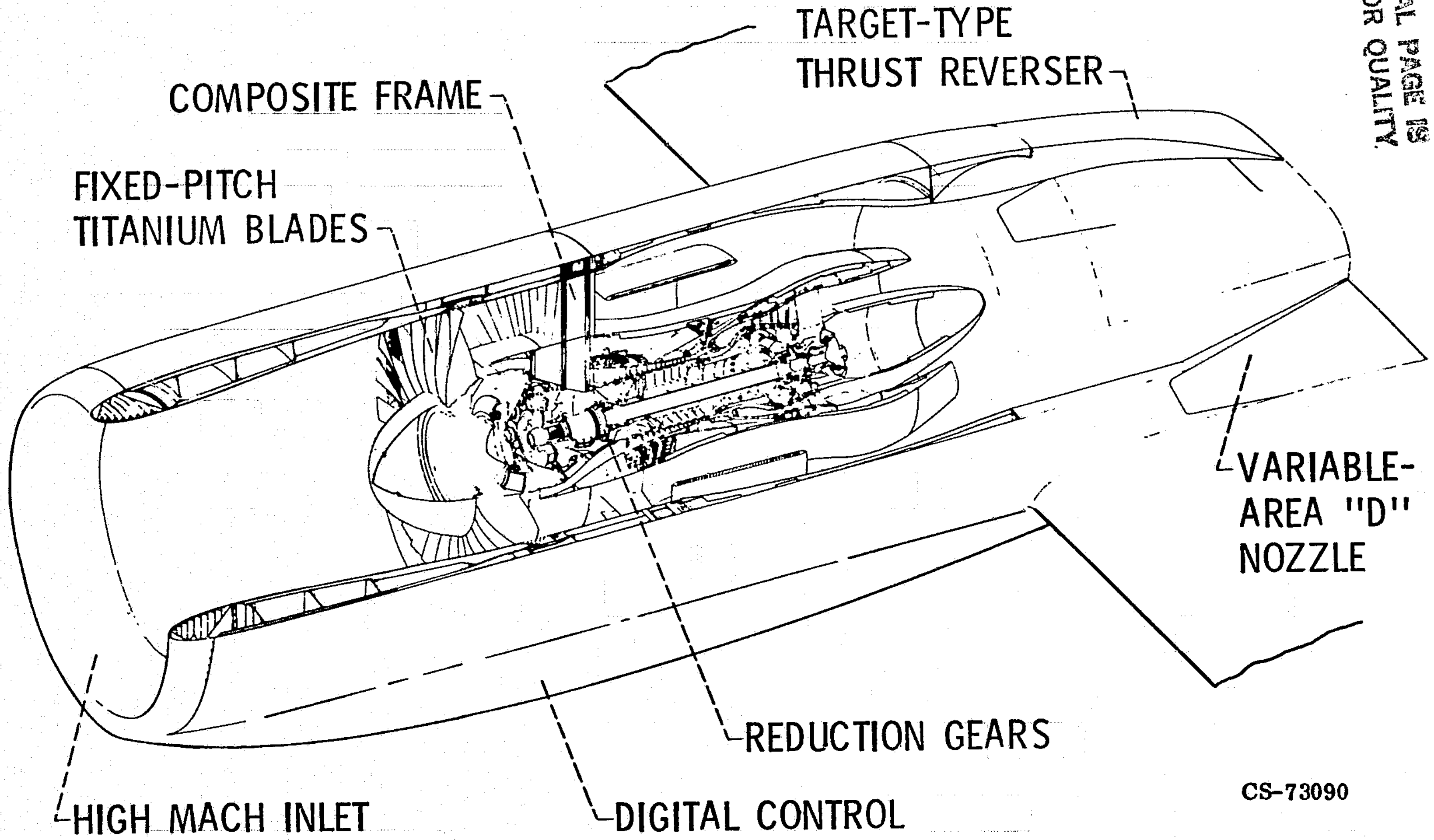


QCSEE UTW ENGINE



CS-73091

OCSEE OTW ENGINE



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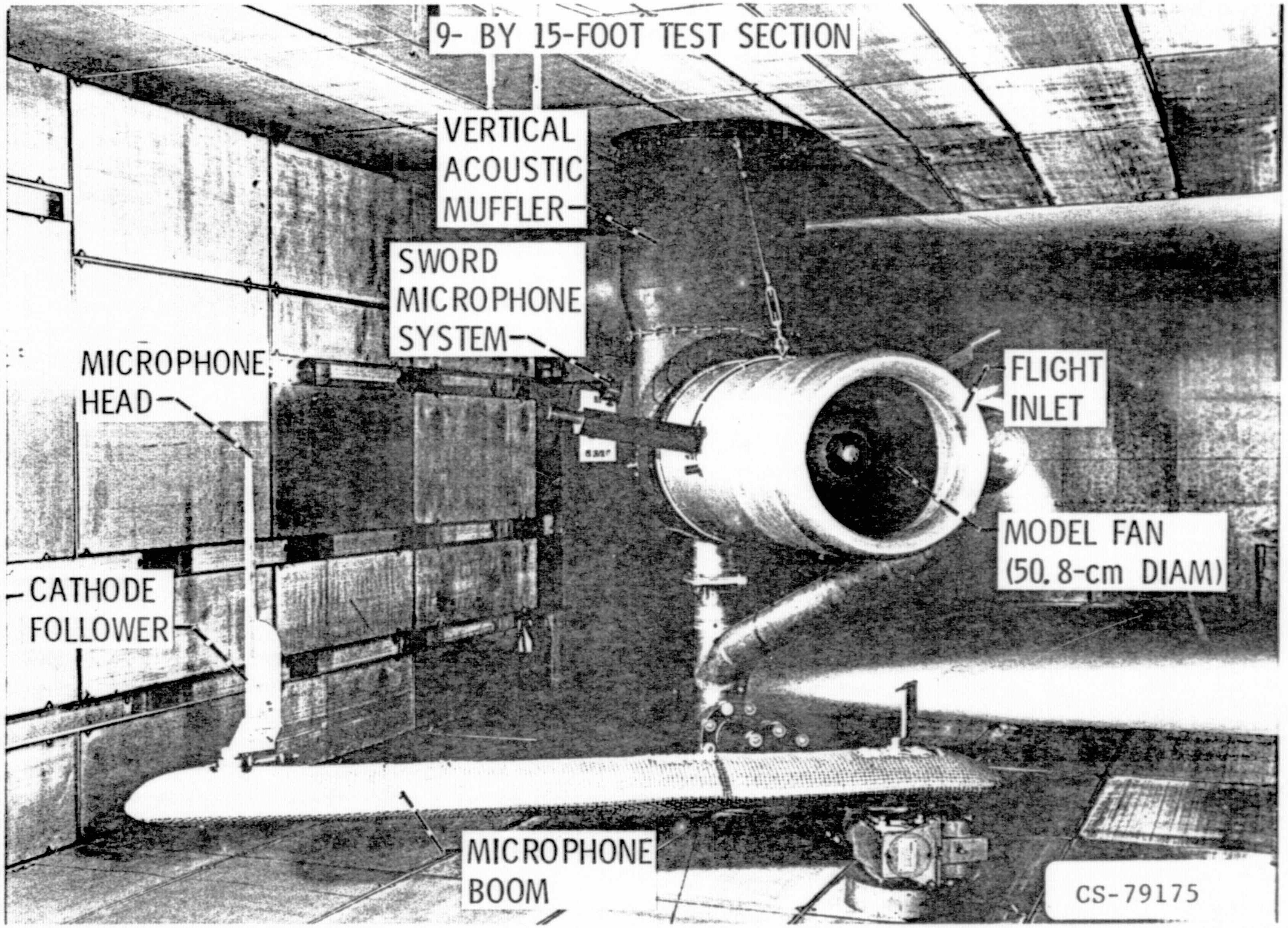
MODEL FAN INSTALLATION



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NASA
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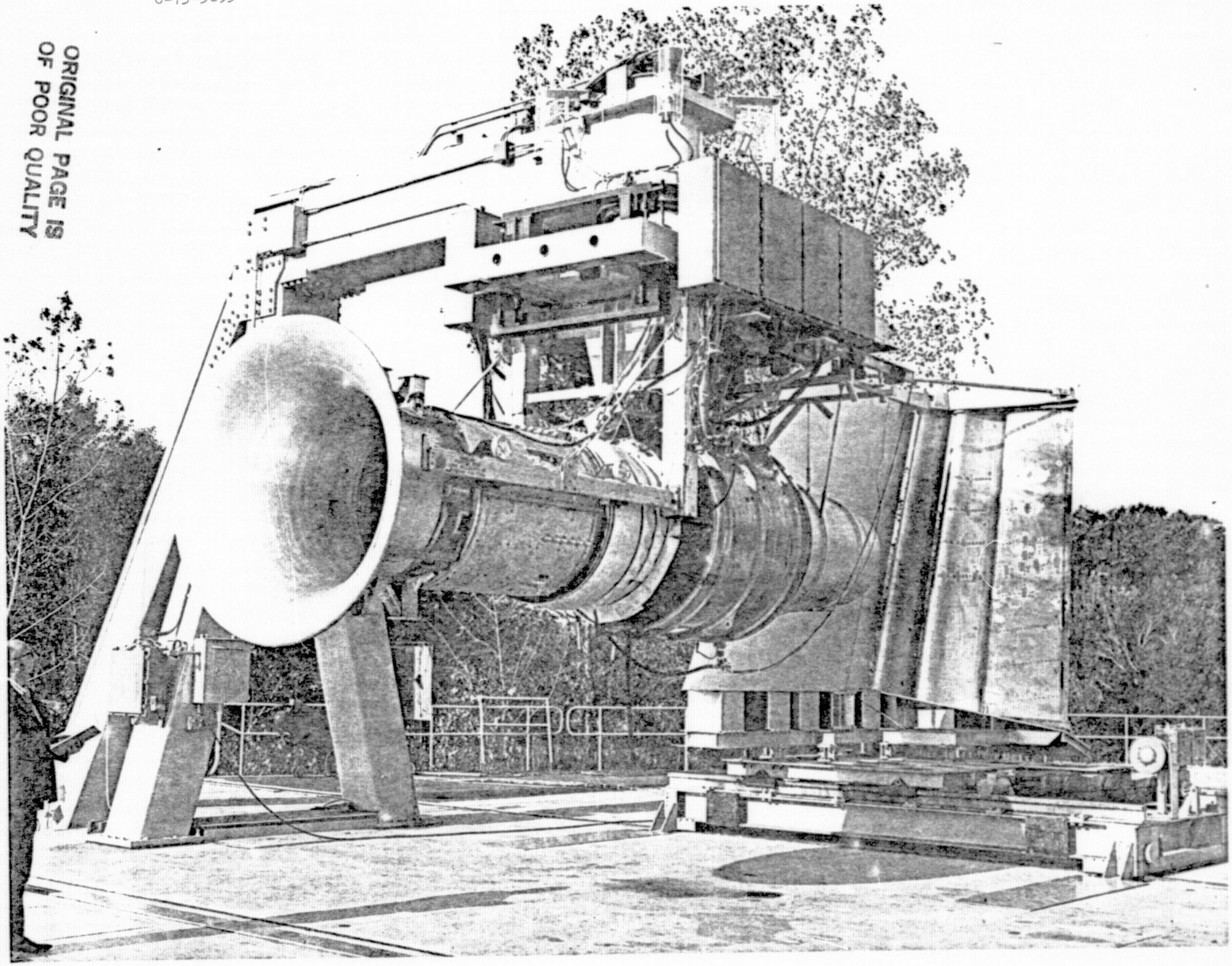
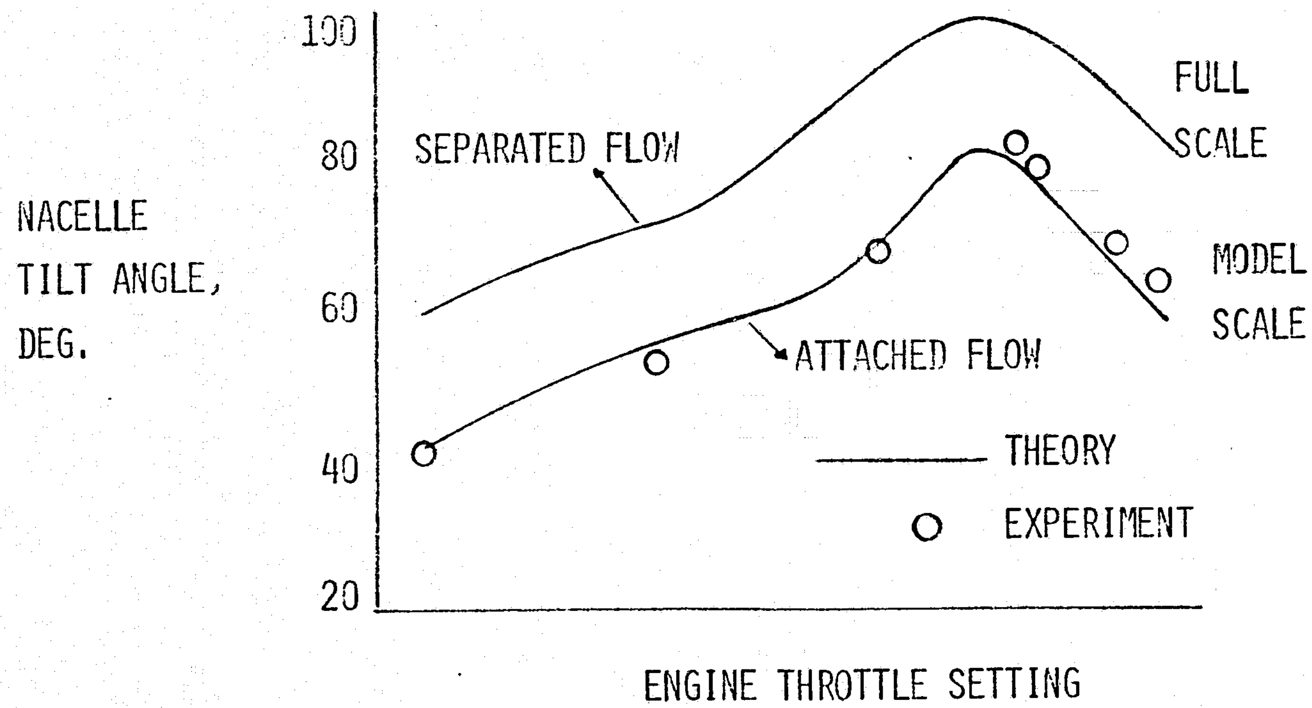


INLET FLOW ANALYSIS



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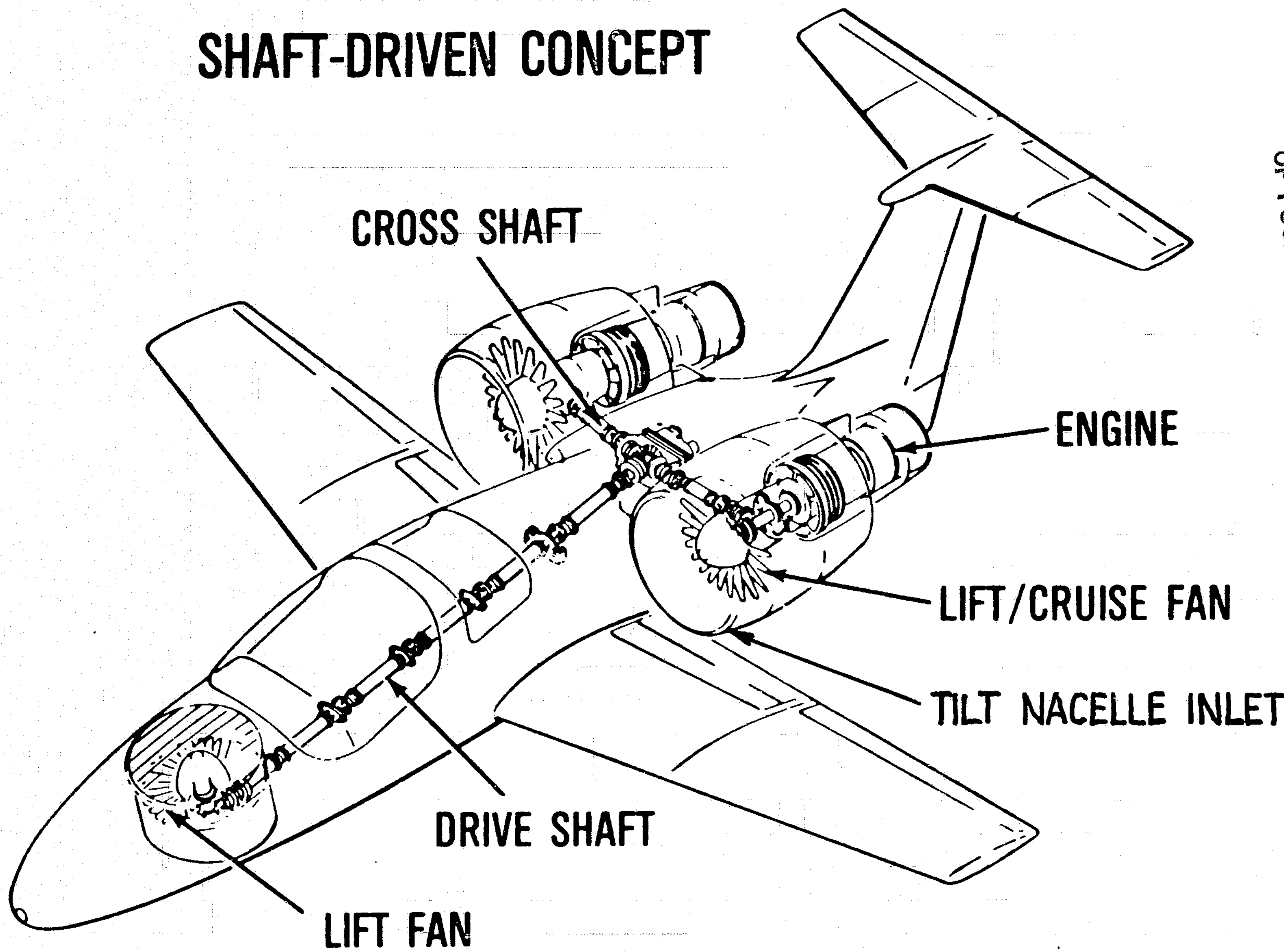
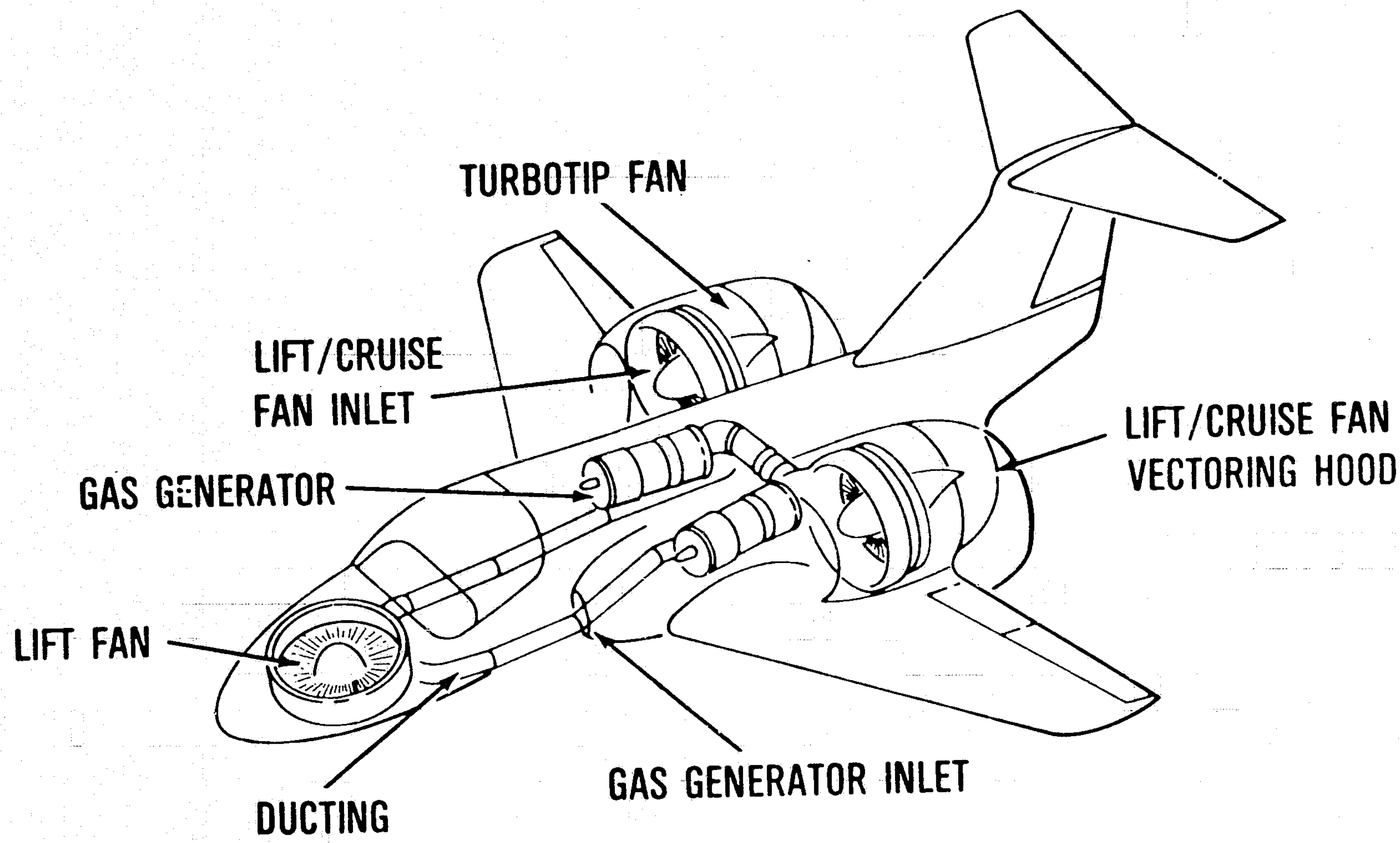
VTOL AIRCRAFT CONFIGURATION

SHAFT-DRIVEN CONCEPT



VTOL AIRCRAFT CONFIGURATION

GAS TIP-DRIVEN CONCEPT



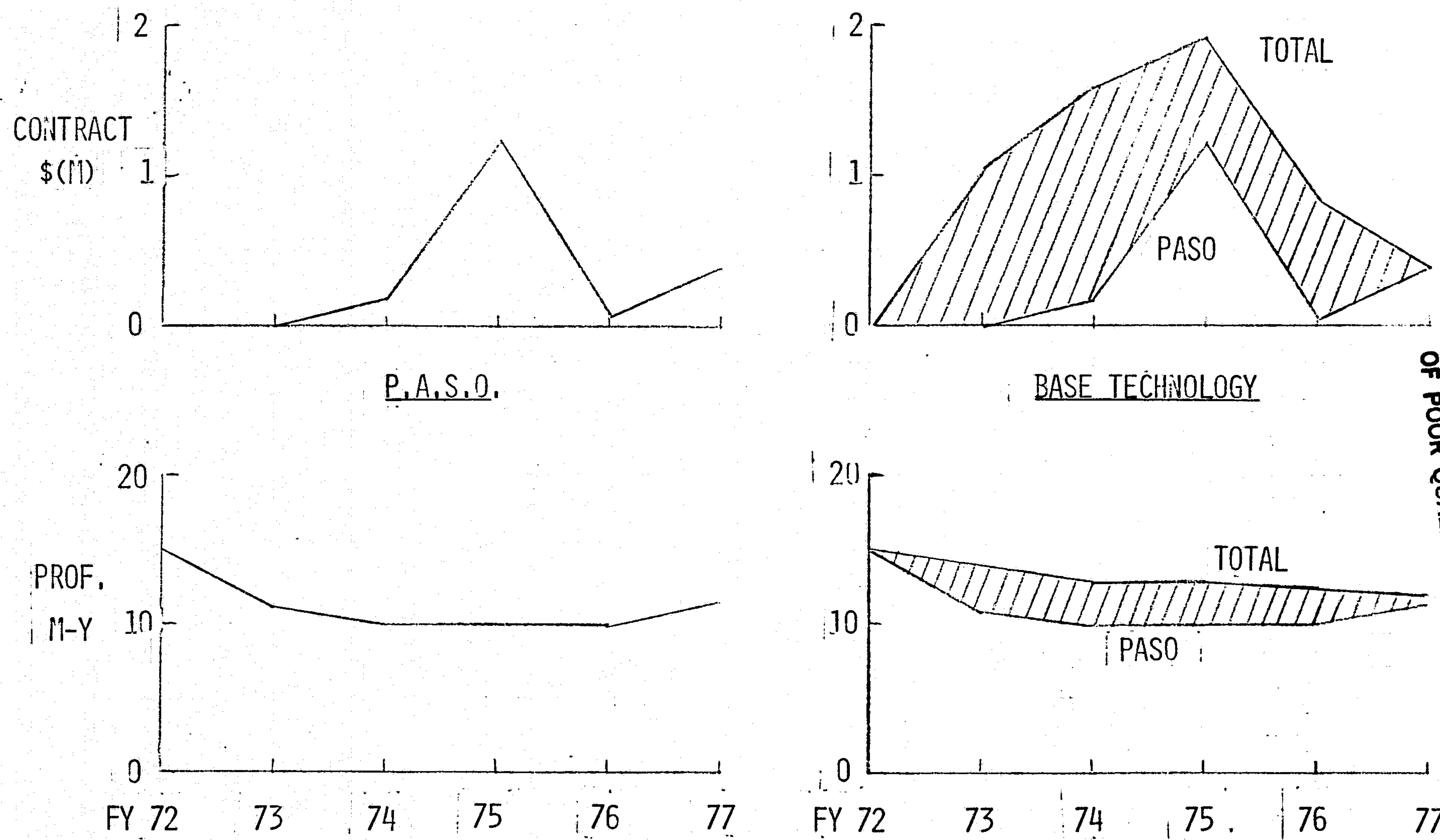
AIRBREATHING ENGINE SYSTEMS

ADVANCED ENGINE SYSTEM CONCEPTS

RICHARD J. WEBER
WIND TUNNEL AND FLIGHT DIVISION

R&T TRENDS

ADVANCED ENGINE SYSTEM CONCEPTS



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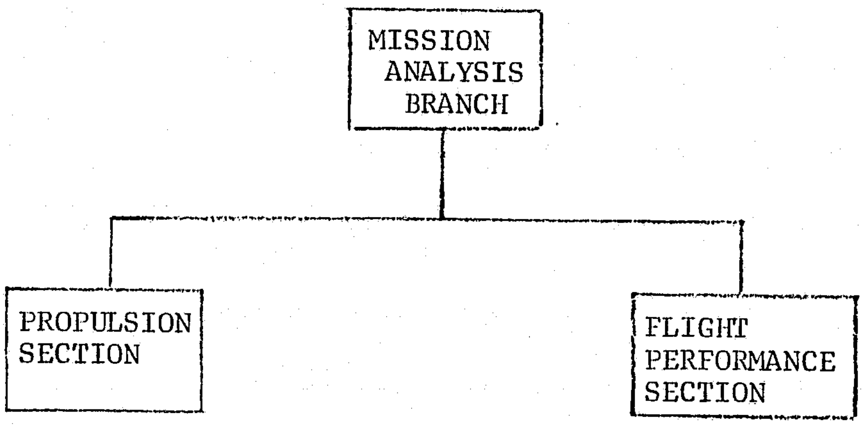
ORGANIZATION



SPECIFIC OBJECTIVE: ADVANCED ENGINE SYSTEM CONCEPTS

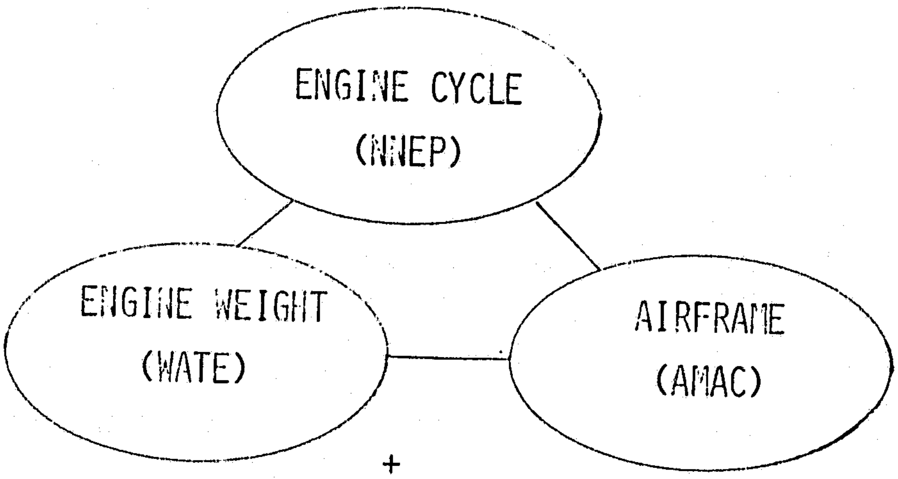
DESCRIPTION: INVESTIGATIONS ARE CONDUCTED TO DETERMINE THE FEASIBILITY AND POTENTIAL BENEFITS OF NEW OR UNUSUAL PROPULSION SYSTEM CONCEPTS FOR FUTURE COMMERCIAL OR MILITARY AIRCRAFT APPLICATIONS.

TARGETS: DEVELOP IMPROVED CAPABILITIES FOR ANALYZING THE PERFORMANCE, WEIGHT AND COST OF ADVANCED PROPULSION SYSTEMS - FY 1979

ASSESS THE MERITS OF ADVANCED VARIABLE CYCLE ENGINE CONCEPTS - 1980

EVALUATE PROPULSION CONCEPTS FOR ADVANCED VTOL AIRCRAFT - 1981

CONTINUING IMPROVEMENT OF TOOLS



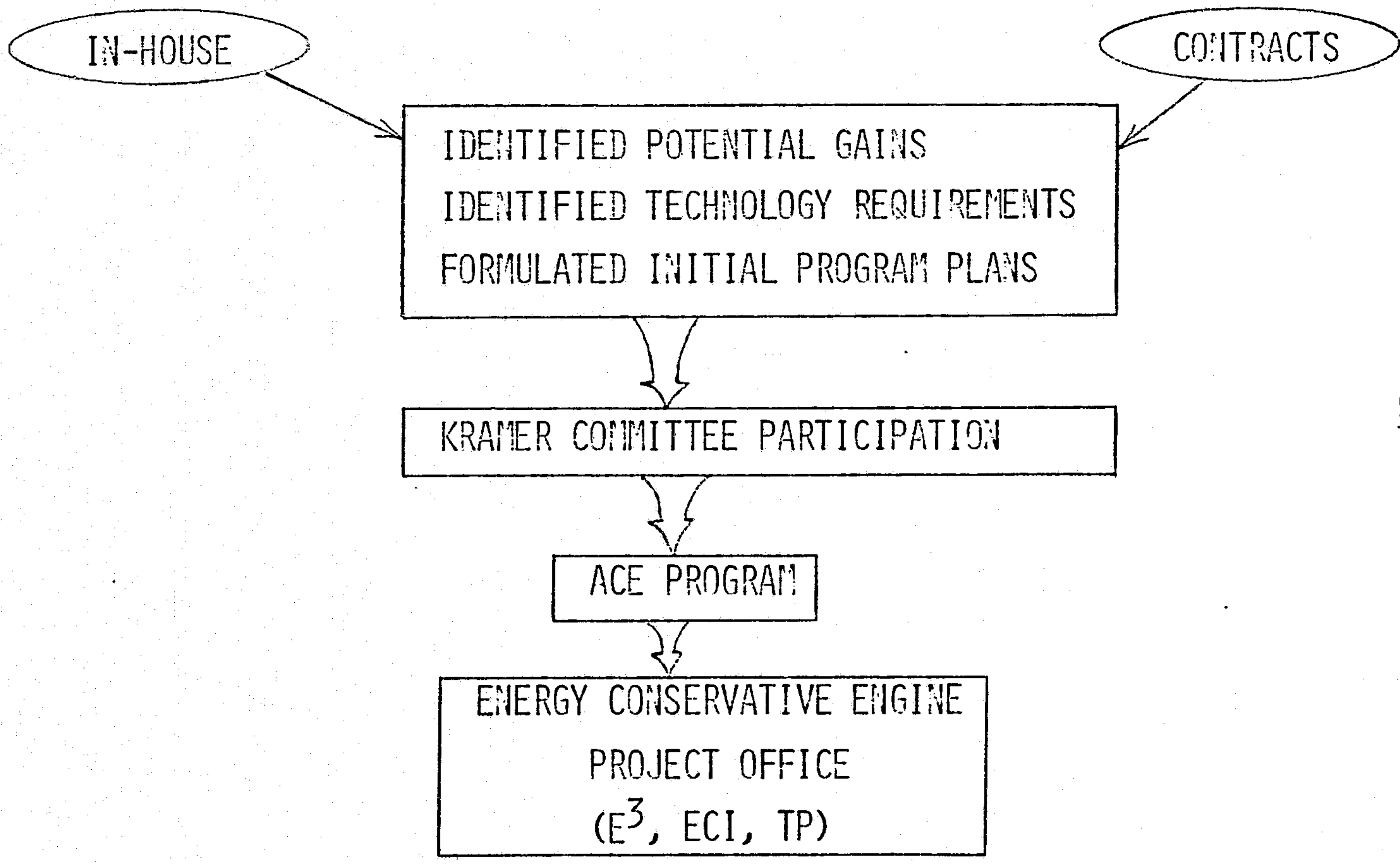
+

INSTALLATION EFFECTS (FY 77)

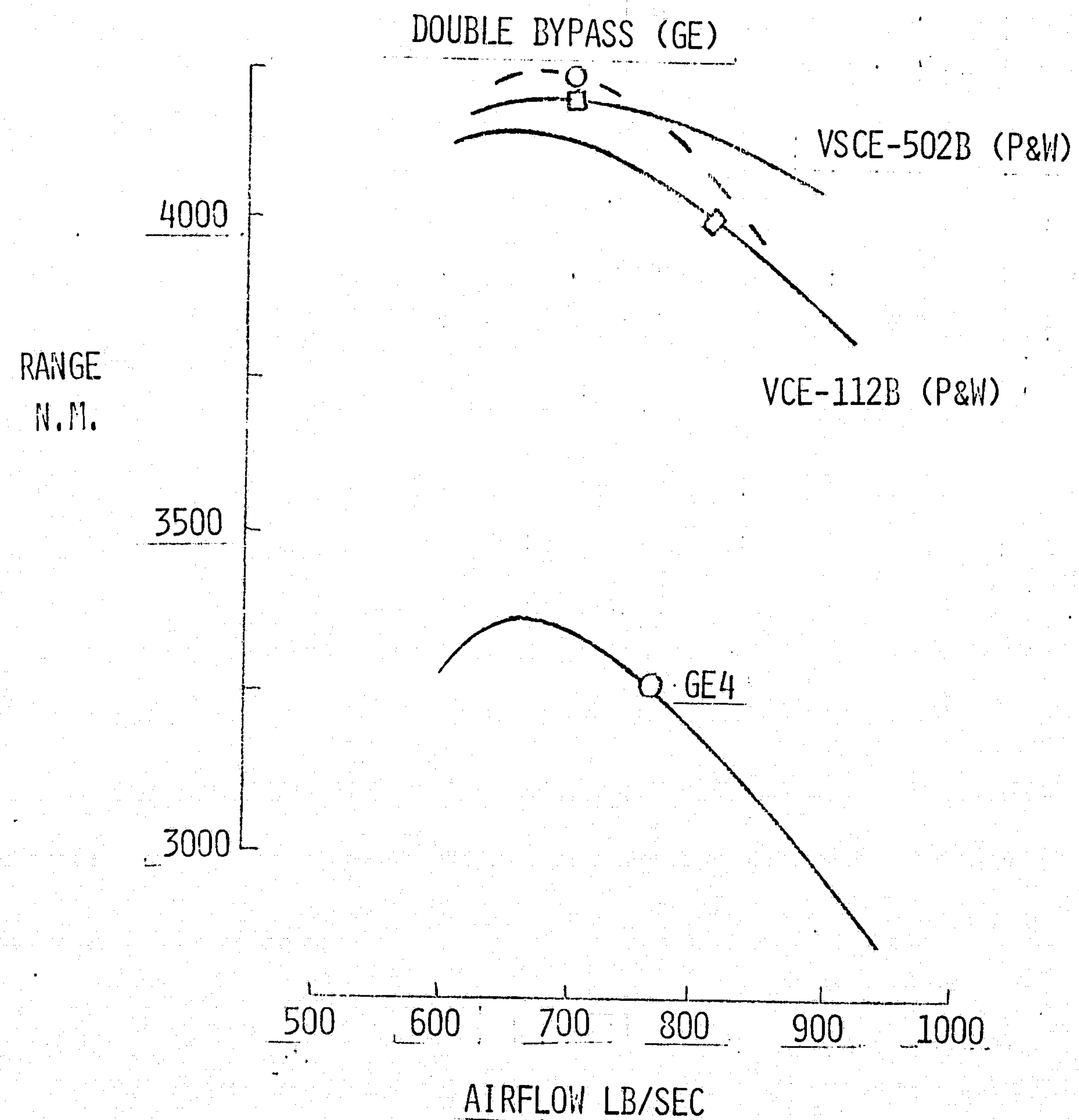
+

LIFE CYCLE COSTS
TIP TURBINES
CENTRIFUGAL COMPRESSORS
MOMENTS OF INERTIA
AERO & MECH. DESIGN LIMITS
MANEUVERING INLETS
2-D INLETS
MAP GENERATORS

OVERVIEW OF FUEL CONSERVATIVE ENGINE STUDIES

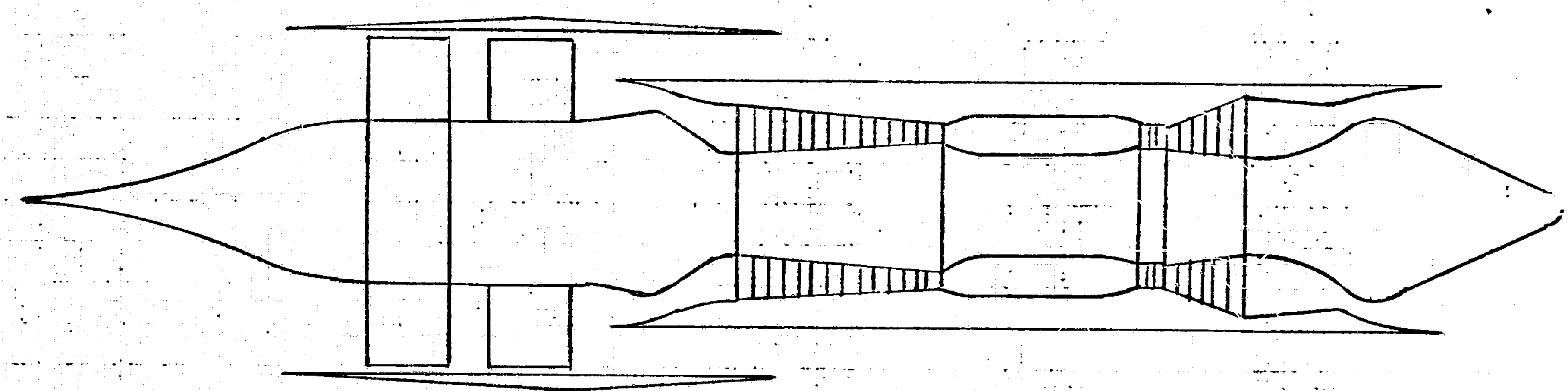


SUPERSONIC TRANSPORT PROPULSION



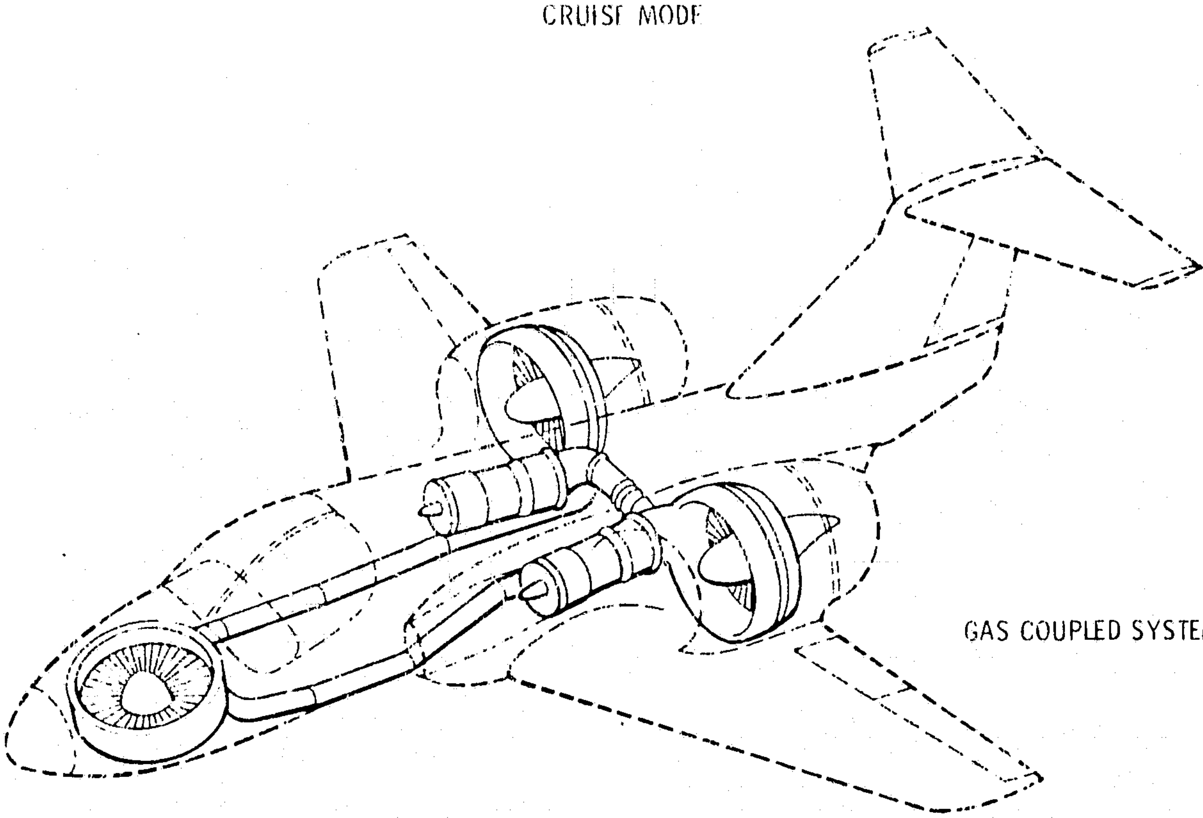
EXAMPLE ALTERNATIVE AST ENGINE CONCEPT

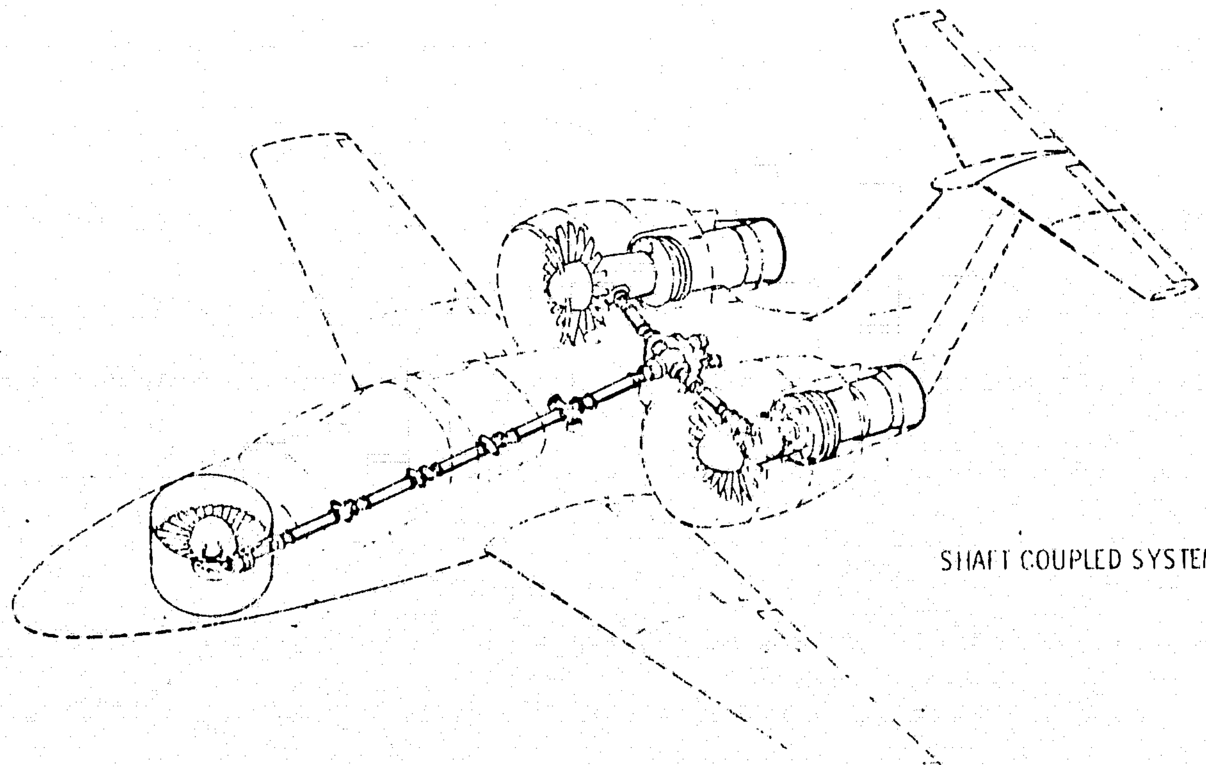
SUPERSONIC FAN ENGINE



TYPICAL LIFT/CRUISE FAN PROPULSION SYSTEMS

CRUISE MODE





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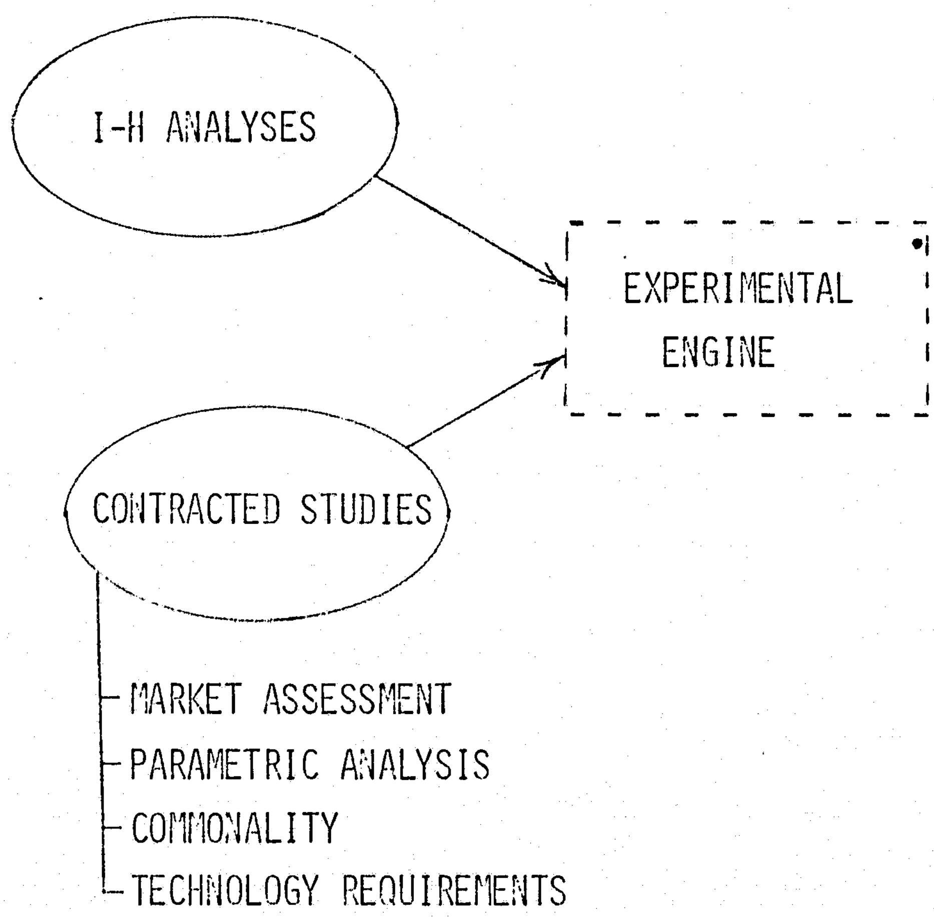
GENERAL AVIATION TURBINE ENGINE (GATE)

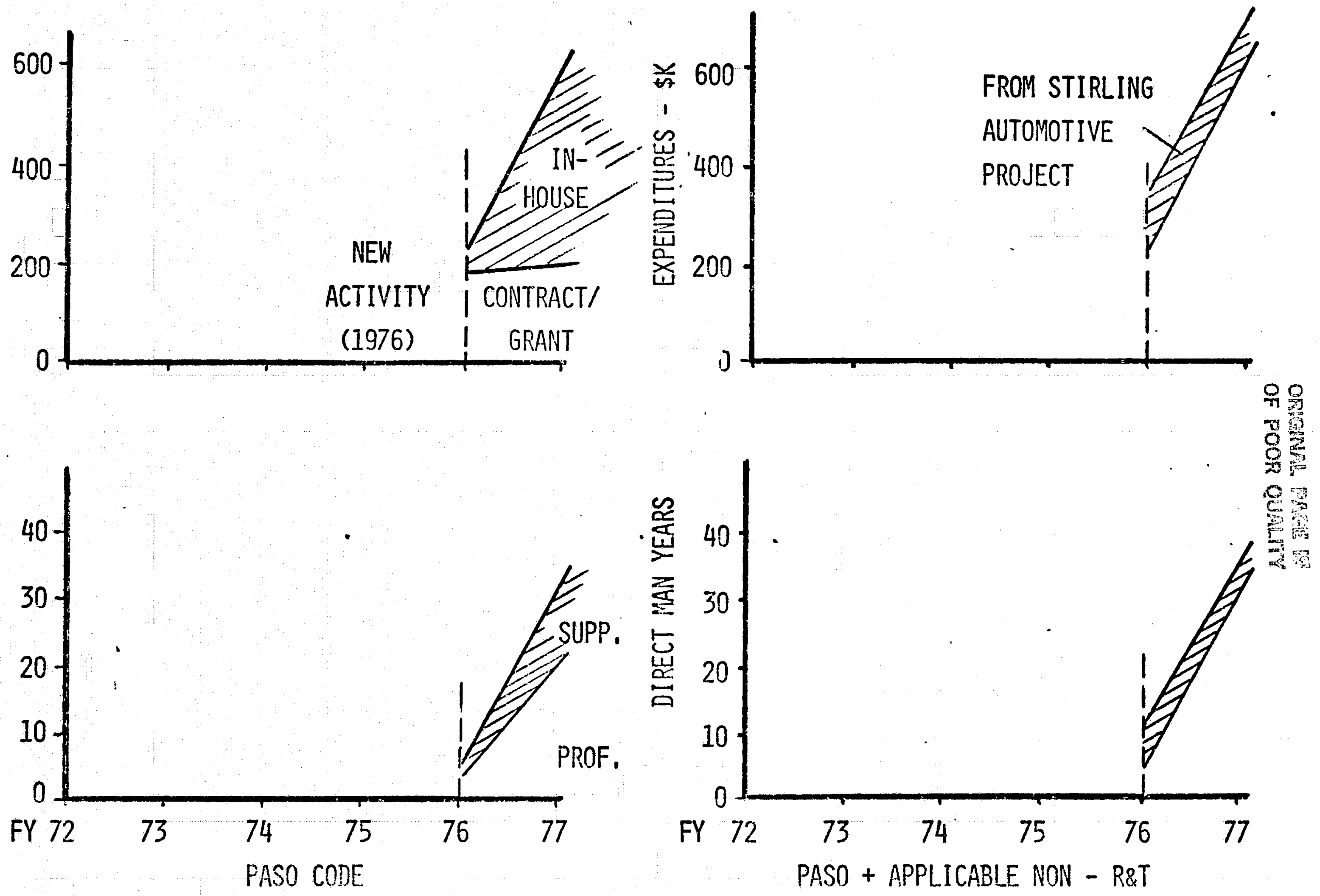


DISCIPLINE/SUBPROGRAM: AIRBREATHING ENGINE SYSTEMS

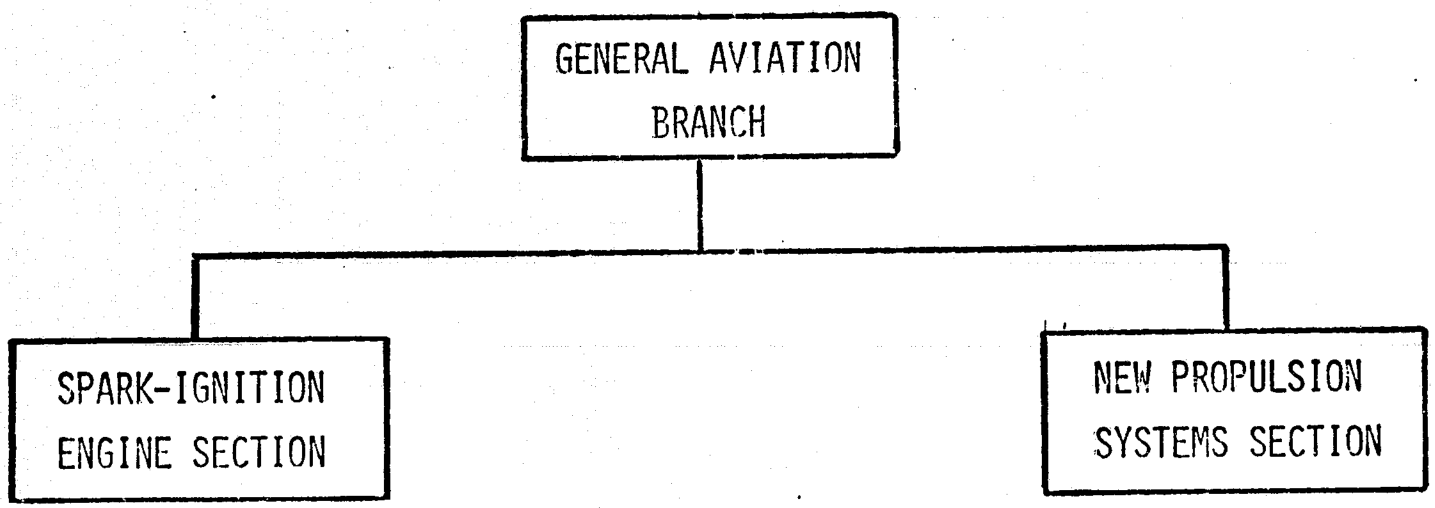
SPECIFIC OBJECTIVE: ADVANCED GENERAL AVIATION PROPULSION RESEARCH

E. A. WILLIS
TRANSPORTATION PROPULSION DIVISION

GENERAL AVIATION - R & T TRENDS



GENERAL AVIATION -- ORGANIZATION



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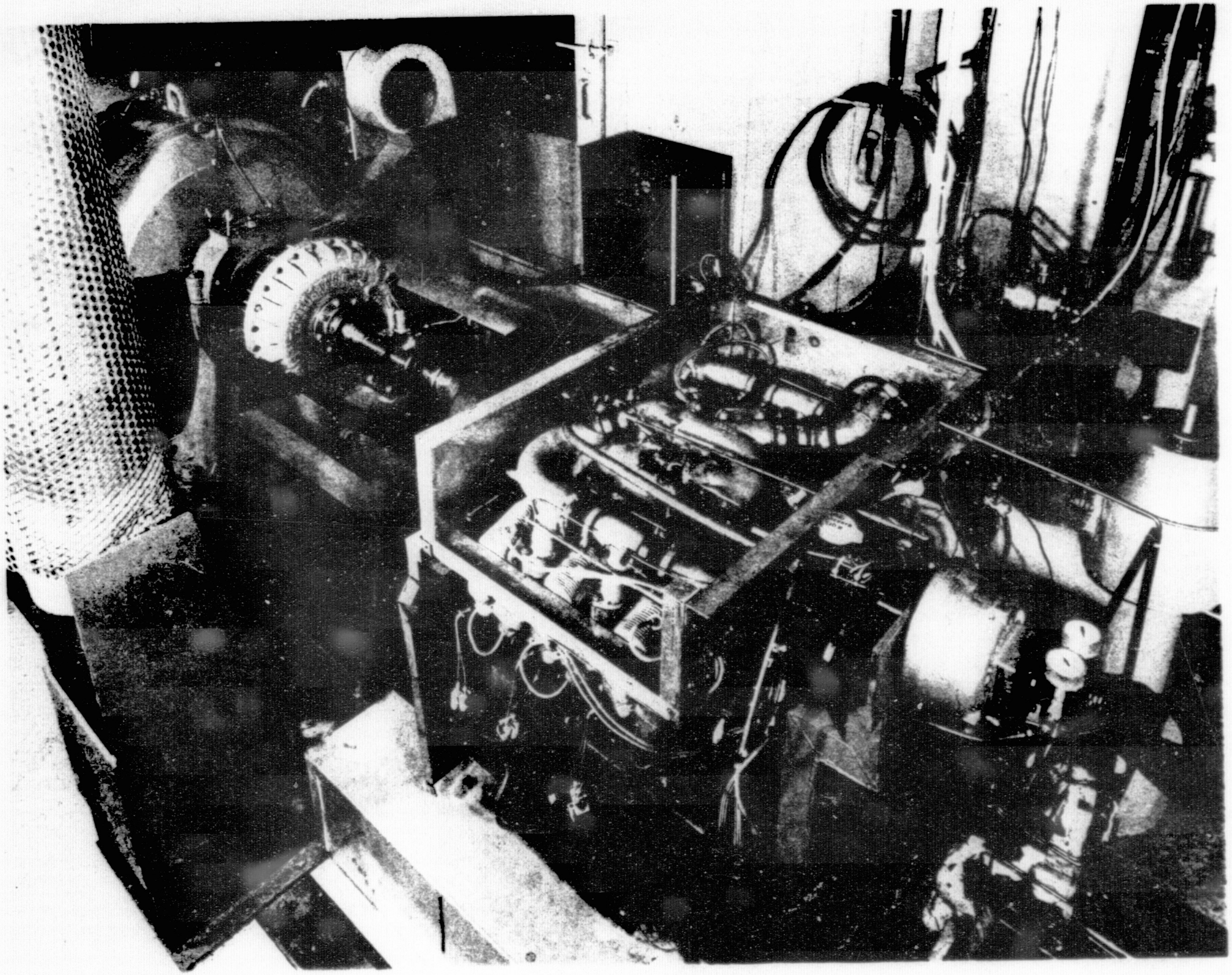
GENERAL AVIATION TEST FACILITIES

FACILITY	ENGINE TYPE	INTAKE & COOLING	DYNAMOMETER HP/RPM
SE-17	AIRCRAFT	TEMPERATURE/HUMIDITY CONTROLLED	300/5000
SE-11	AUTOMOTIVE	AMBIENT INTAKE WATER COOLED	250/4500
SE-12	SINGLE-CYLINDER RESEARCH (SPARK-IGNITION)	AMBIENT INTAKE WATER COOLED	50/5000
SE-6	SINGLE-CYLINDER RESEARCH (DIESEL)	AMBIENT/HEATED INTAKE WATER COOLED	125/5000

C-76-4501



ADVANCED GENERAL AVIATION PROPULSION RESEARCH

SPECIFIC OBJECTIVE

ALTERNATIVE ENGINES, INCLUDING DIESEL, ROTARY AND STIRLING, WILL BE STUDIED AND THE BEST CANDIDATE COMPARED TO CONVENTIONAL AND IMPROVED SPARK-IGNITION (S-I) ENGINES.

TARGETS

- OTTO CYCLE SIMULATION COMPUTER CODE - FY 1979
- ALTERNATIVE ENGINE SELECTION - FY 1979
- DESIGN DATA FOR ADVANCED CYLINDER HEADS AND DUCTING - FY 1980

TARGET: OTTO CYCLE SIMULATION CODE

PROGRAM ELEMENTS: IN-HOUSE

- CYCLE-TO-CYCLE VARIATIONS
- VALVE TIMING & MANIFOLD MASS FLOW CHARACTERIZATION
- PISTON BLOWBY
- IMPROVED HC EMISSIONS PREDICTIONS

TARGET: ALTERNATIVE ENGINE SELECTION

PROGRAM ELEMENTS: IN-HOUSE

- LIGHTWEIGHT DIESEL (SEMI-INDEPENDENT TURBOCHARGER)
- STIRLING

CONTRACT/GRANT

- LIGHTWEIGHT DIESEL (UNIVERSITY OF MICHIGAN
- ROTARY ENGINE (CURTISS-WRIGHT)
- ADVANCED SPARK-IGNITION
- STIRLING

TARGET: DESIGN DATA FOR ADVANCED CYLINDER HEADS & DUCTING

PROGRAM ELEMENTS: IN-HOUSE

- COOLING FINS STUDY FOR SMALL A/C ENGINES

8

UNIQUE OTTO CYCLE SIMULATION CODE

(CONTINUING DEVELOPMENT)

1. FINITE BURNING INTERVAL
2. DETAILED CHEMICAL KINETICS THROUGHOUT COMBUSTION & EXPANSION PROCESS
3. COMPLETE CYCLE (720°)
4. SOME ABILITY TO PREDICT HC EMISSIONS
5. CAN USE THREE DIFFERENT HEAT TRANSFER RELATIONS THROUGHOUT CYCLE

7

UNIQUE INSTRUMENTATION FOR COMBUSTION PHENOMENA

- REAL TIME MEASUREMENT OF % CHARGE BURNED, COMBUSTION INTERVAL, IGNITION LAG, TIMING ANGLE & IMEP
- 100 CYCLE AVERAGE & STD. DEVIATION OF COMB. PARAMETERS
- SENSES CONTROL PARAMETERS SUCH AS IMEP FOR NEW CLOSED-LOOP CONTROL SYSTEMS
- UNIQUE UTILIZATION OF ELECTRONIC DEVICES
- EXAMPLE: IDENTIFICATION OF HC EMISSIONS SOURCE AT IDLE (MISFIRING)